OCTOBER 1961

METAL PROGRESS

OPEN UP: for better carbon steels

By restoring carbon at the surface of high-carbon and alloy steel strip which has been surface decarburized during previous processing, and by making high-carbon or nitrogen steel from soft, easily rolled steels . . . better, more uniform, high-strength steels are achieved more economically by the amazing new Open Coil Process of Gas Alloying. For further details, write *Lee Wilson Engineering Co., Inc., 20005 Lake Road, Cleveland 16, Ohio.*

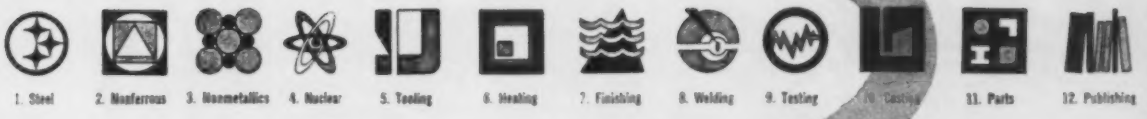
Circle 1421 on Page 48-B

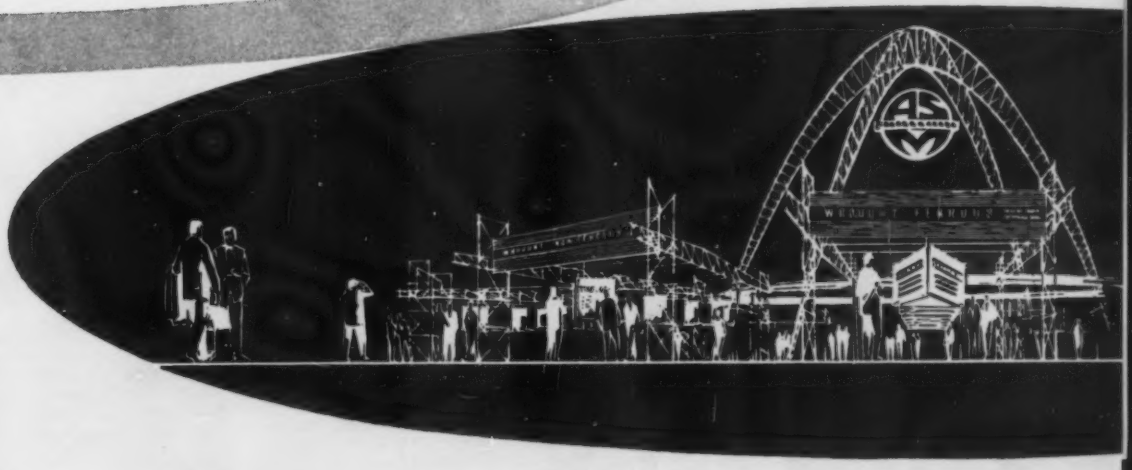
Lee Wilson

ORIGINATORS AND LEADING PRODUCERS OF OPEN COIL AND SINGLE STACK FURNACES

Metal Show Issue **METAL PROGRESS** OCTOBER 1961

43RD NATIONAL METAL CONGRESS AND EXPOSITION





A list of exhibitors, the technical programs, and admission-registration to the show.

EXHIBITORS

The Exhibitors at the Metal Show are classified into 12 areas of the metals industry. Under each classification appears the name of the exhibiting company followed by a booth number. Thus, under Classification 1, Ferrous Metals, the exhibitor is listed as Al-Fin Corp and the display is located in Booth 1011.

1. **Ferrous Metals**
2. **Nonferrous Metals**
3. **Related Engineering Materials**
4. **Nuclear Materials and Equipment**
5. **Tool Materials, Cutting and Forming Equipment**
6. **Industrial Heating Equipment and Supplies**
7. **Cleaning and Finishing Equipment and Supplies**
8. **Welding and Joining Equipment and Supplies**
9. **Testing, Inspection, Control and Research**
10. **Production and Casting Equipment and Supplies**
11. **Parts, Forms, and Shapes for Design and Application**
12. **Publishers, Societies and Associations**

Ferrous Metal Producers and Distributors

Acipco Special Products Div. American Cast Iron Pipe Co. 1230
Al-Fin Corp. 1011
Allegheny Ludlum Steel Corp. 572
Alloy Metal Abrasive Co. 1151
Avon Tube Div. Higbie Mfg. Co. 834
Babcock & Wilcox Co. Tubular Products Div. 462
Canada—Dept. of Trade & Commerce 210
Central Foundry Div. General Motors Corp. 252
W. M. Chace Co. 227
Chromalloy Corp. 248
Copperweld Steel Co. Aristoloy Steel Div. 448
Curtiss-Wright Corp. Metals Processing Div. 1208
Daystrom, Inc. Weston Instrument Div. 339
Detroit Hinge Mfg. Co. 1257
Wilbur B. Driver Co. 314
Electro-Alloys Div. American Brake Shoe Co. 428
Exomet, Inc. 934
Gleason Works 154
Great Lakes Steel Corp. 772
Harrison Engineering Corp. 157
Howe Sound Co. 862
Inductotherm Corp. 921
Industrial Furnace Co., Div. of AAA Machinery & Equip. Co. 607
International Nickel Co. 472
Jones & Laughlin Steel Corp. Stainless & Strip Div. 839
Korhumel Steel & Aluminum Co. 948
Laboratory Equipment Corp. 1053
LaSalle Steel Co. 730
Leeds & Northrup Co. 639
Lynchburg Foundry Co. 363
Martin Engineering Co. 1059
McLouth Steel Corp. 850
Merrill Brothers 910
Republic Steel Corp. 638
C. A. Roberts Co. 1211
Service Steel Div. Van Pelt Corp. 532
Sharon Steel Corp. 1171
Superior Tube Co. 1032
Timken Roller Bearing Co. Steel & Tube Div. 739
Ulbrich Stainless Steels, Inc. 538
United States Steel Corp. 630
U.S. Pipe and Foundry Co., Steel and Tubes Div. 1262
Vanadium-Alloys Steel Co. 557
Vanadium Corp. of America 338
Webb Forging Co. 956
Westinghouse Electric Corp. 529
Youngstown Sheet & Tube Co. 968

Nonferrous Metal Producers and Distributors

Al-Fin Corp. 1011
Alloy Metal Abrasive Co. 1151
Aluminum Co. of America 528
Beryllium Corp. 963
J. Bishop & Co. Platinum Works 438
Canada—Dept. of Trade & Commerce 210
Central Foundry Div. General Motors Corp. 252
W. M. Chace Co. 227
Cobalt Information Center 539
Cooper Metallurgical Associates 229
Copper and Brass Sales, Inc. 830
Curtiss-Wright Corp. Metals Processing Div. 1208
Daystrom, Inc. Weston Instrument Div. 339
Wilbur B. Driver Co. 314
Engelhard Industries, Inc. 1150
Exomet, Inc. 934
General Electric Co. Metallurgical Products Dept. 262
Harrison Engineering Corp. 157
Howe Sound Co. 862
Inductotherm Corp. 921
Industrial Furnace Co., Div. of AAA Machinery & Equip. Co. 607
International Nickel Co. 472
Kawecki Chemical Co. 1249
Kester Solder Co. 231
Laboratory Equipment Corp. 1053
Martin Engineering Co. 1059
C. A. Roberts Co. 1211
Stauffer Metals Co. 456
Superior Tube Co. 1032
Tin Research Institute, Inc. 537
Union Carbide Corp. 127
Union Carbide Metals Co. Div. of Union Carbide Corp. 127
Univertical Corp. 1225
Upton Electric Furnace Co. 909
Vanadium Corp. of America 338

Related Engineering Materials

Alloy Surfaces Co., Inc. 808
Aluminum Co. of America 528
Beryllium Corp. 963
J. Bishop & Co Platinum Works 438
Cam-Lok Div. Empire Products, Inc. 1055
Canada—Dept. of Trade & Commerce 210
W. M. Chace Co. 227
Furane Plastics Inc. 1227
General Electric Co., Lamp Metals and Components Dept. 262
Heil Process Equipment Corp. 411
Howe Sound Co. 862
National Carbon Co. Div. of Union Carbide Corp. 127
Stauffer Metals Co. 456
Steco Corp. 255
Tempil Corp. 928
Union Carbide Corp. 127

Nuclear Materials and Equipment

Al-Fin Corp. 1011
Allegheny Ludlum Steel Corp. 572
Arcweld Sales Co. 356
Beryllium Corp. 963
J. Bishop & Co. Platinum Works 438
Budd Co. 220
Chromalloy Corp. 248
Cincinnati Sub Zero Products 1033
Cooper Metallurgical Associates 229
Daystrom, Inc. Weston Instrument Div. 339
Harper Electric Furnace Corp. 433
International Nickel Co. 472
National Carbon Co. Div. of Union Carbide Corp. 127
Nuclear Materials & Equipment Corp. 455
Picker X-Ray Corp. 1221
Stauffer Metals Co. 456
F. J. Stokes Corp. 268
Tempil Corp. 928
Union Carbide Corp. 127
Westinghouse Electric Corp. 529

Tool Materials, Cutting and Forming Equipment

Allegheny Ludlum Steel Corp. 572
Allison-Campbell Div. American Chain & Cable Co. 514
American Pullmax Co., Inc. 349
Artco, Inc. 160
Atkins Saw Div., Borg-Warner Corp. 1233
Cyril Bath Co. 408
Beaver Pipe Tools, Inc. 906
Canada—Dept. of Trade & Commerce 210
Cavitron Equipment Corp. 610
Clearing Div., U.S. Industries 1244
Cobalt Information Center 539
Cooper Metallurgical Associates 229
Curtiss-Wright Corp. 1208
Dake Corp. 168
Elox Corp. of Michigan 961
Furane Plastics Inc. 1227
General Electric Co. Metallurgical Products Dept. 262
Hamilton-Electrona, Inc. 232
Jiffy Disintegrators, Inc. 211
Lennox Tool & Machine Builders 810
Modern Mfg. Co. 219
J. A. Richards Co. 1263
Super Alloy Forge Inc. 1010
Texaco, Inc. 473
Timken Roller Bearing Co. Steel & Tube Div. 739
Union Carbide Corp. 127
Wells Manufacturing Corp. 1111
S. S. White Industrial Div. 1034
Wickman Products Corp. 1113

Industrial Heating Equipment and Supplies

Ajax Electric Co. 452
Allvac Metals Co. 734
Alpha Electric Refrigeration Co. 259
American Gas Furnace Co. 821
Anderson Engineering 1207
Arcweld Sales Co. 356
Ashworth Bros., Inc. 463
Audubon Metalwove Belt Div. Manganese Steel Forge Co. 633
W. M. Chace Co. 227
Commercial Steel Treating Corp. 1007
Daystrom, Inc. Weston Instrument Div. 339
Despatch Oven Co. 714
Detroit Edison Co. 1234
Dry Clime Lamp Corp. 1056
Eclipse Fuel Engineering Co. 1073
Electric Furnace Co. 306
Electric Steam Products, Inc. 316
Electro-Alloys Div. American Brake Shoe Co. 428
Exomet, Inc. 934
Harper Electric Furnace Corp. 433
Harris Manufacturing Co., Inc. 1215
Harrison Engineering Corp. 721
C. I. Hayes, Inc. 938
Heil Process Equipment Corp. 411
Hevi-Duty Electric Co., Div. of Basic Products Corp. 151
Holcroft & Co. 353
E. F. Houghton & Co. 621
Inductotherm Corp. 921
Industrial Furnace Co., Div. of AAA Machinery & Equip. Co. 607
Ipsen Industries, Inc. 161
Kolene Corp. 420
Lake Chemical Co. 1162
Leeds & Northrup Co. 639
Lepel High Frequency Labs. 962
Lindberg Engineering Co. 706
Marquardt Corp. 738
Joe Martin Co., Inc. 221
Midland-Ross Corp. 672
National Induction Heating 1051
Ohio Chankshaft Co., Tocco Div. 238
Park Chemical Co. 907
J. O. Ross Engineering Div. Midland-Ross Corp. 672
Selas Corp. of America 872
Sentry Co. 930
Spencer Turbine Co. 215
Sunbeam Corp. 721
Surface Combustion Div. Midland-Ross Corp. 672
Tempil Corp. 928
Waukee Engineering Co., Inc. 137
Westinghouse Electric Corp. 529
Wheelco Instruments Div. Barber-Colman Co. 1134
Lee Wilson Engineering Co. 332

Cleaning and Finishing Equipment and Supplies

Acme Manufacturing Co. 263
Ajem Laboratories, Inc. 1048
Aldridge Industrial Oils, Inc. 415
Allen Aircraft Products 457
Alloy Metal Abrasive Co. 1151
Armour Alliance Industries 1251
Ashland Oil & Refining Co. 513
Autosonics, Inc. 409
Balcrank, Inc. 225
Binks Manufacturing Co. 138
G. S. Blakeslee & Co. 1029
Branson Instruments, Inc. 838
Centri-Spray Corp. 1048
Dow Chemical Co. 320
E. I. du Pont De Nemours & Co. 1028
Globe Industries, Inc. Vibrodyne and Supermet Div. 1229
Gray Company, Inc. 333
Heil Process Equipment Corp. 411
E. F. Houghton & Co. 621
R. O. Hull & Co., Inc. 162
Kolene Corp. 420
Manpro Corp. 1238
Martin Engineering Co. 1059
Merit Products Inc. 1235
Metalwash Machinery Corp. 1220
Minnesota Mining & Mfg. Co. 828
Mobile Oil Co. 1130
Murray-Way Corp. 1209
Nordson Corp. 216
Oakite Products, Inc. 1138
Pangborn Corp. 620
Pennsalt Chemicals Corp. 310
Phillips Mfg. Co. 1052
Progressive Chemical & Equip. Corp. 920
Ransburg Electro-Coating Corp. 171
Roto-Finish Ranschoff Co. 1120
Southwestern Engineering Co. 814
F. J. Stokes Corp. 268
Tempil Corp. 928
Turco Products, Inc. 421
United Clamp Mfg. Co. 1009
Vapor Blast Mfg. Co. 212
Waldron-Hartig Div. Midland-Ross Corp. 672
Waukee Engineering Co. 137
Weltronic Co. 1072
Westinghouse Electric Corp. 529
Wheel Trueing Tool Co. 350
Wyandotte Chemical Corp. 1127

Welding and Joining Equipment and Supplies

Aerobraze Corp. 908
American Gas Furnace Co. 821
American Machine & Foundry Co. 711
Cam-Lok Div. Empire Products, Inc. 1055
Canada—Dept. of Trade & Commerce 210
Copper and Brass Sales, Inc. 830
Exomet, Inc. 934
Gregory Industries, Inc. 148
Hamilton-Electrona, Inc. 232

Aldridge Industrial Oils, Inc. 415
Allen Aircraft Products 457
Alloy Metal Abrasive Co. 1151
Armour Alliance Industries 1251
Ashland Oil & Refining Co. 513
Autosonics, Inc. 409
Balcrank, Inc. 225
Binks Manufacturing Co. 138
G. S. Blakeslee & Co. 1029
Branson Instruments, Inc. 838
Centri-Spray Corp. 1048
Dow Chemical Co. 320
E. I. du Pont De Nemours & Co. 1028
Globe Industries, Inc.
Vibrodyne and Supermet Div. 1229
Gray Company, Inc. 333
Heil Process Equipment Corp. 411
E. F. Houghton & Co. 621
R. O. Hull & Co., Inc. 162
Kolene Corp. 420
Manpro Corp. 1238
Martin Engineering Co. 1059
Merit Products Inc. 1235
Metalwash Machinery Corp. 1220
Minnesota Mining & Mfg. Co. 828
Mobile Oil Co. 1130
Murray-Way Corp. 1209
Nordson Corp. 216
Oakite Products, Inc. 1138
Pangborn Corp. 620
Pennsalt Chemicals Corp. 310
Phillips Mfg. Co. 1052
Progressive Chemical & Equip. Corp. 920
Ransburg Electro-Coating Corp. 171
Roto-Finish Ranschoff Co. 1120
Southwestern Engineering Co. 814
F. J. Stokes Corp. 268
Tempil Corp. 928
Turco Products, Inc. 421
United Clamp Mfg. Co. 1009
Vapor Blast Mfg. Co. 212
Waldron-Hartig Div.
Midland-Ross Corp. 672
Waukee Engineering Co. 137
Weltronic Co. 1072
Westinghouse Electric Corp. 529
Wheel Trueing Tool Co. 350
Wyandotte Chemical Corp. 1127

Welding and Joining Equipment and Supplies

Aerobraze Corp. 908
American Gas Furnace Co. 821
American Machine & Foundry Co. 711
Cam-Lok Div.
Empire Products, Inc. 1055
Canada—Dept. of Trade & Commerce 210
Copper and Brass Sales, Inc. 830
Exomet, Inc. 934
Gregory Industries, Inc. 148
Hamilton-Electrona, Inc. 232
Hobart Brothers Co. 720
Howe Sound Co. 862
Lake Chemicals Co. 1162
Lapeer Mfg. Co. 1039
Lepel High Frequency Labs. 962
Lincoln Electric Co. 868
Linde Co., Div. of
Union Carbide Corp. 127
Merrill Brothers 910
Motor City Tool & Die 1014
Nelson Stud Welding Div. 148
Tempil Corp. 928
United Clamp Mfg. Co. 1009
Wall Colmonoy Corp. 933
Weltronic Co. 1072
Westinghouse Electric Corp. 529

Testing, Inspection, Control and Research

Ajem Laboratories, Inc. 1048
Alloy Metal Abrasive Co. 1151
Alnor Instrument Div.
Illinois Testing Lab. 915
American Cystoscope Makers 1112
American Optical Co.
Instrument Div. 954
Arcweld Sales Co. 356
Assembly Products, Inc. 1008
Baird-Atomic, Inc. 253
Bausch & Lomb Inc. 232
Branson Instruments, Inc. 838
Brinkmann Instruments Inc. 1129
Budd Co. 220
Buehler Ltd. 520
Canada—Dept. of Trade & Commerce 210
Cavitron Equipment Corp. 610
Central Foundry Div.
General Motors Corp. 252
Centri-Spray Corp. 1048
W. M. Chace Co. 227
Collins Microflat Co., Inc. 1057
Curtiss-Wright Corp. 1208
Daystrom, Inc.
Weston Instrument Div. 339
Detroit Testing Machine Co. 806
Elion Ultrasonics, Inc. 1063
William J. Hacker & Co. 1020
Hardric Laboratories, Inc. 1115
Harris Manufacturing Co. 1215
Howe Sound Co. 862
Instron Engineering Corp. 1021
Instrument Development Labs. 1153
King Tester Corp. 914
Laboratory Equipment Corp. 1053
Latronics Corp. 1135
Leeds & Northrup Co. 639
E. Leitz, Inc. 1049
Magnaflux Corp. 368
Magnetic Analysis Corp. 1015
Markal Co. 1162
Marquardt Corp. 738
Martin Engineering Co. 1059
Mettler Instrument Corp. 1255
Micrometrical Mfg. Co. 239
Mine Safety Appliances Co. 811
Minneapolis-Honeywell Regulator 820
National Induction Heating 1051
Nuclear Materials & Equipment Corp. 455
Olsen Scientific Instruments 217
Tinius Olsen Testing Machine Co. 329
Perkin-Elmer Corp. 1157
Picker X-Ray Corp. 1221
Princeton Div.
Curtiss-Wright Corp. 1208
Pyrometer Instrument Co. 431
Radiation Electronics Co., Comptometer Corp. 929
Research & Control Instruments 1133
Riehle Testing Machine Div.
American Machine & Metals 829 & 429
Sieburg Industries, Inc. 414
Sperry Products Co. 1108
Steel City Testing Machines Div.
American Machine & Metals 429
F. J. Stokes Corp. 268
Tempil Corp. 928
Torsion Balance Div.
American Machine & Metals 257
Turco Products, Inc. 421
United Clamp Mfg. Co. 1009
Unitron Instrument Co. 508
Waukee Engineering Co. 137
Weltronic Co. 1072
West Instrument Corp. 412
Westinghouse Electric Corp. 529
Wheelco Instruments Div.
Barber-Colman Co. 1134
Wiedemann Machine Co. 521

Production and Casting Equipment and Supplies

Ajax Magnethermic Corp. 346
Al-Fin Corp. 1011
Aluminum Co. of America 528
Artco, Inc. 160
Canada—Dept. of Trade & Commerce 210
Curtiss-Wright Corp. 1208
Daystrom, Inc.
Weston Instrument Div. 339
Detroit Hinge Mfg. Co. 1257
General Alloys Co. 603
Hoffman Industries Inc. 1155
E. F. Houghton & Co. 621
Small AC Motor & Generator Dept.
General Electric Co. 262
Howe Soun.. Co. 862
Inductotherm Corp. 921
Kawecki Chemical Co. 1249
Leeds & Northrup Co. 639
Marquette Div.
Curtiss-Wright Corp. 1208
Martin Engineering Co. 1059
Metals Processing Div.
Curtiss-Wright Corp. 1208
National Carbon Co., Div. of
Union Carbide Corp. 127
Relton Corp. 1259
Spencer Turbine Co. 215
Stauffer Metals Co. 456

811	F. J. Stokes Corp.	268
820	Surface Combustion Div.	
1051	Midland-Ross Corp.	672
	Tempil Corp.	928
455	Union Carbine Corp.	127
217	Union Carbide Metals Co.	
329	Div. of Union Carbide Corp.	127
1157	Wales Strippit Div.	
1221	Houdaille Industries	130
	Wall Colmonoy Corp.	933
1208		
431		

Parts, Forms, Shapes for Design and Application

929	Allegheny Ludlum Steel Corp.	572
1133	Alloy Products Corp.	935
& 429	Aluminum Co. of America	528
414	Babcock & Wilcox Co.	
1108	Tabular Products Div.	462
429	J. Bishop & Co.	
268	Platinum Works	438
926	Canada—Dept. of Trade &	
	Commerce	210
257	Centri-Spray Corp.	1048
421	W. M. Chace Co.	227
1009	Cobalt Information Center	539
508	Copper and Brass Sales	830
137	Detroit Hinge Mfg. Co.	1257
1072	Heli-Coil Corp.	434
412	Howe Sound Co.	862
529	Marquardt Corp.	738
	Merrill Brothers	910
1134	National Carbon Co., Div. of	
521	Union Carbide Corp.	127
	New Hermes Engraving	
ting	Machine Corp.	917
olies	Precision Extrusions, Inc.	1131
	Timken Roller Bearing Co.	
	Steel & Tube Div.	739
346	Union Carbide Corp.	127
1011	Univertical Corp.	1225
528	Wall Colmonoy Corp.	933
160	Westinghouse Electric Corp.	529
	Will-O-Hill Industries, Inc.	1253
210	Wilson Mechanical	
1208	Instruments Div.	952
339		
1257		
603		
1155		

Publishers, Societies and Associations

621	American Metal Market	1156
	American Society for Metals	650
262	Bureau of Foreign Commerce	120
862	Chilton Co.	710
921	Industrial Heating	451
1249	Industrial Press	1035
639	Industrial Publishing Corp.	430
	Industrial Research	911
1208	Metal Progress	650
1059	Metal Treating Institute	515
	Metalworking News	413
1208	Penton Publishing Co.	328
	Small Business Administration	150
127	Social Security Administration	1012
1259	Special Libraries Association	256
215	Thomas Publishing Co.	1261
456	U.S. Department of Commerce	120

Technical Programs of ASM and Cooperating Societies

Sessions of interest to everyone will be presented by the American Society for Metals; Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers; Society for Nondestructive Testing; American Welding Society; Industrial Heating Equipment Association; Metal Powder Industries Federation; Metal Treating Institute; Ultrasonic Manufacturers Association; American Gas Association; and Special Libraries Association

ASM Seminar—Ultra-High Purity Metals

Oct. 21-22, Cobo Hall

Sat. 9:00 a.m.

Chairman: W. C. Ellis, Bell Telephone Laboratories

Why Ultra-Pure Metals? . . . W. G. Pfann, Bell Telephone Labs.

Ion Exchange Methods for Obtaining Pure Metals . . . F. H. Spedding, J. E. Powell, Iowa State U.

Pure Metals From Chemical Processes . . . H. A. Wilhelm, David Peterson, Iowa State University

Sat. 2:00 p.m.

Chairman: W. D. Robertson, Yale

Electrolytic Preparation of Pure Metals . . . D. H. Baker, Jr., T. A. Henrie, U.S. Bureau of Mines

Purification by Zone Melting and Very High-Temperature Melting Techniques . . . J. H. Wernick, Bell Telephone Laboratories

Analysis for Trace Elements . . . Ph. Albert, Vitry Laboratories, Paris

Sun. 9:00 a.m.

Chairman: W. R. Hibbard, Jr., General Electric Co.

Mechanical Properties of High-Purity Metals . . . R. L. Smith, A. A. Hendrickson, Michigan Tech

Some Annealing Phenomena in Ultra-High Purity Metals . . . K. T. Aust, J. W. Rutter, General Electric Co.

Metallographic Problems Resolved by Using Metals of Very High Purity . . . G. Chaudron, Vitry Laboratories, Paris

Sun. 2:00 p.m.

Chairman: F. L. Vogel, RCA

Effect of Trace Impurities on Electrical Properties . . . J. E. Kunzler, Bell Telephone Laboratories

Effect of Trace Impurities on Thermoelectric Properties . . . W. P. Pearson, National Research Council, Canada

Electromagnetic Properties of High-Purity Metals . . . W. A. Harrison, General Electric Co.

ASM Technical

Study of Carbide Composition and Microstructure During Quenching and Tempering of 5% Cr-Mo-V Steel . . . G. P. Contractor, W. A. Morgan, Dept. of Mines and Technical Surveys; E. G. Schempp, Atlas Steels, Ltd.

Creep Behavior of Austenitic Stainless Steel as Effected by Carbides Precipitated on Dislocations . . . F. Garofalo, F. Von Gemmingen, W. F. Domis, U.S. Steel Corp.

Microstructural and Residual Stress Changes in Hardened Steel Due to Rolling Contact . . . J. J. Bush, W. L. Grube, G. H. Robinson, General Motors Corp.

Electron Transmission Study of Tempering of Martensite in 0.42% C Steel . . . A. M. Turkalo, General Electric Co.

Tues. 2:00 p.m.
Iron-Chromium Alloys

Chairmen: T. W. Eichelberger, Westinghouse Research Laboratories and R. F. Hehemann, Case Institute of Technology

Influence of Delta Ferrite-Carbide Segregates on Properties of 12% Cr Steel . . . E. A. Loria, Climax Molybdenum Co.

Submicroscopic Structures in Tempering 410 Stainless Steel . . . J. J. Hauser, J. M. Capenos, B. R. Banerjee, Crucible Steel Co.

Relationship Between Fatigue and Damping Characteristics and Microstructure of 12% Cr Steel . . . E. J. Dulis, V. K. Chandhok, Crucible Steel Co. of America; J. P. Hirth, Carnegie Institute

Wed. 2:00 p.m.
Nuclear Metals

Chairmen: R. E. Swift, University of Kentucky and H. H. Chiswik, Argonne National Laboratory

Liquidus Curves of Bismuth Fission-Product Systems . . . D. G. Schweitzer, J. R. Weeks, Brookhaven National Lab.

Effects of Alkali Metals on Solubility of U in Bi . . . D. G. Schweitzer, J. R. Weeks, Brookhaven Lab.

Metallographic Studies of Al-Ni-U Bonds in Nuclear Fuel Elements . . . C. L. Angerman, DuPont Co.

Effect of Oxygen on Properties of Zircaloy-2 . . . L. S. Rubenstein, F. L. Shubert, J. G. Goodwin, Westinghouse Electric Corp.

Influence of Warm Prestressing on Notch Properties of Several High-Strength Alloys . . . E. A. Steigerwald, Thompson - Ramo - Woold - ridge, Inc.

Strain Hardening Properties of High-Strength Sheet . . . F. R. Larson, J. Nunes, Watertown Arsenal Laboratories

Additive Effects of Alloying Elements on Mechanical Properties of Cast Austenitic Alloys at 1500° F. . . . D. L. Sponseller, R. A. Flinn, University of Michigan; R. W. Kraft, United Aircraft Corp.

Hardness Anisotropy of Cb . . . D. L. Douglass, General Electric Co.

Thurs. 2:00 p.m.
Space-Age Metals—II

Chairmen: S. W. Poole, Republic Steel Corp.; W. F. Brown, N.A.S.A.

Constitution and Transformation Behavior of Ti-8Al-8Zr-1(Ta + Cb) Alloy . . . H. Margolin, New York University; E. Ence, Republic Aviation Corp.

Investigation of Notch Sensitivity in A-286 Alloy . . . G. B. Heydt, Carpenter Steel Co.

Mechanical Properties of Unalloyed V . . . J. W. Farrell, Union Carbide Metals Co.

Effect of Temperature Exposure on Microstructure of Ni-4.5% Al-3.5% Ti Alloy . . . J. F. Radavich, Purdue University; W. H. Couts, G.E. Co.

Thurs. 2:00 p.m.
Corrosion

Chairmen: P. D. Frost and F. W. Fink, Battelle Memorial Institute

Morphology of Grain Boundary Carbides and Its Influence on Intergranular Corrosion of 304 Stainless . . . R. Stickler, A. Vinckier, Westinghouse Electric Corp.

Corrosion Resistance and Mechanical Properties of Ti-Mo Alloys Containing Noble Metals . . . C. R. Bishop, Union Carbide Metals Co.; M. Stern, Linde Co.

Investigation of Effects of Fabrication Variables on Corrosion Resistance of Zircaloy-2 . . . H. S. Kalish, Nuclear Fuel Research Laboratory; H. M. Cobb, Olin Mathieson Chemical Corp.

Propagation of Stress - Corrosion Cracking in Mg Alloy . . . W. M. Pardue, Battelle Memorial Institute; F. H. Beck, M. G. Fontana, Ohio State University

Chemical Milling . . . G. H. Fox, Jr., Turco Products
Electrolytic Metal Removal Processes . . . L. A. Williams, Anocut Engineering Co.
Ultrasonic Machining . . . P. A Sorenson, Raytheon Corp.
Electrical Discharge Machining . . . D. H. Hill, General Motors Co.

Thurs. 9:00 a.m.
Nonmetallic Materials

Chairman: J. Young, DuPont Co.
Economics of Plastic Moldings vs. Metal Die Castings . . . G. L. Graf, Jr., DuPont Co.
Composition and Properties of High-Strength Adhesives . . . G. A. Jikka, General Motors Corp.
Fusion Bonding—New Method for Combining Plastic and Metal . . . W. R. Pascoe, Polymer Corp.
Newer Plastic Materials—Effect On Metals Industry . . . H. McCann, Modern Plastics Magazine

Thurs. 2:00 p.m.
Light Metals

Chairman: F. Bayer, Jr., Chevrolet
Magnesium and Automobiles . . . F. L. Burkett, Dow Chemical Co.
Creativity with Aluminum and New Aluminum Applications . . . E. J. deRidder, Reynolds Metal Co.
Beryllium—A Space Age Metal . . . T. J. Hughel, General Motors

ASM-AIME Joint Session

Oct. 22, Statler-Hilton Hotel

Sun. 8:00 p.m.
Professional Activities

Chairmen: W. R. Hibbard, Jr., General Electric Co. and W. D. Manley, ORNL
Program of the Metallurgy and Ceramics Foundation . . . G. A. Roberts, Vanadium-Alloy Steels Corp.
Establishing a National Academy of Engineering . . . H. Work, Engineering Foundation

Special ASM Program—Vacuum Techniques in Metallurgy

Oct. 23, Cobo Hall

Mon. 2:00 p.m.

Vacuum Processing Theory . . . H. W. Westeren, C. I. Hayes, Inc.
Vacuum Theory & Applications . . . C. Norndorf, Consolidated Vacuum
Vacuum Furnace Instrumentation and Controls . . . P. Webster, Minneapolis-Honeywell Regulator
Vacuum Furnace Practice . . . R. Korf, Woodward Governor Co.

Metallurgical Society Fall Meeting

Oct. 23-26, Pick-Fort Shelby

Mon. 9:00 a.m.

Preparation and Analysis of High-Purity Iron and Its Dilute Solid Solutions . . . R. L. Smith, B. Park, J. A. Van Westenberg, Michigan College of Mining and Technology
On the Iron Phase Transformation at High Pressures . . . R. S. Davis, Arthur D. Little Inc.
Thermal, Magnetic, and Electrical Properties of Fe With Various Solutes . . . A. Arrott, J. E. Noakes, Ford Motor Co.

Mon. 2:00 p.m.
Processing of Refractory Metals

Chairman: W. H. Rostoker, Armour Research Foundation, V. E. Pulsifer, Fansteel Metallurgical Corp.
Processing and Properties of Arc Cast Tungsten Sheet . . . C. F. Mueller, W. J. Schoenfeld, Universal-Cyclops Steel Corp.
Arc Melting and Hot Workability of Tungsten Alloys . . . R. G. Carlson, General Electric Co.
Evaluation of Variables In Production of Arc-Cast Mo Alloy Sheet . . . W. A. McNeish, Universal-Cyclops Steel Corp.
Processing and Properties of Mo Mill Products from Massive Isostatically Pressed and Sintered Billets . . . L. L. France, F. P. Giannakos, Universal - Cyclops
Effect of Microstructure on Workability and Properties of Vacuum Hot Pressed Cb Alloy . . . T. L. Robertshaw, R. G. Frank, General Electric Co.; I. Perlmutter, Wright Air Development Div.
Techniques for Preparation of High-Purity Refractory Metals . . . E. Fenn, M. Badiali, R. Bakish, Alloyd Corp.
Strength of Sintered Ni-W . . . J. N. Brophy, H. W. Hayden, J. Wulff, Mass. Institute of Technology

Mon. 2:00 p.m.
Dislocations and Their Interactions
(Abstract Session)

Chairmen: T. L. Johnston, Ford Motor Co.; N. Brown, University Of Pennsylvania

Mon. 2:00 p.m.
Effects of Surface and Environment on Strength—II

Chairman: C. S. Barrett, University of Chicago
Interaction of Surfaces and Dislocations . . . A. K. Head, Commonwealth Scientific and Industrial Research Organization, Melbourne
Variation of Barrett Anomalous After-Effect With Torsion . . . D. B. Holt, University of Witwatersrand
Influence of Thin Films of Solid Non-organic Compounds on Strength Properties of Metals . . . L. Nanis, J. H. Schulman, Columbia University
Effect of Surface on Mechanical Deformation of Metal Single Crystals . . . I. R. Kramer, Martin Co.
Role of Surface on Strength, Ductility and Embrittlement of Metals . . . A. Berghezan, European Research Associates

Mon. 2:00 p.m.
High-Purity Iron and Its Dilute Solid Solutions—II

Chairman: M. Gensamer, Columbia

Substructure and Mechanical Properties of Refractory Metals . . . S. Allen, E. M. Passmore, B. S. Lement, Manufacturing Labs.
Flow Characteristics of Zone-Refined Mo Over Temperature Range 4.2° K to 373° K . . . J. Van den Sype, R. Maddin, University of Pennsylvania; A. Lawley, Franklin Institute Laboratories
Flow and Fracture of High-Purity Ta-W Alloys in Ductile-Brittle Transition Region . . . D. P. Ferriss, DuPont Co.; R. M. Rose, J. J. Wulff, M.I.T.
Notch Sensitivity of Refractory Metals . . . A. C. Imgram, F. C. Holden, H. R. Ogden, R. I. Jaffee, Battelle Memorial Institute
Effects of Dispersions on Recrystallization and Ductile-Brittle Transition Behavior of W . . . R. I. Jaffee, B. C. Allen, D. J. Maykuth, Battelle Memorial Institute
Yield and Fracture in Polycrystalline Ta . . . M. A. Adams, Materials Research Corp.

Tues. 2:00 p.m.
Working of Cast Structures

Chairmen: T. E. Dancy, Jones & Laughlin Steel Corp.; C. F. Schrader, Inland Steel Co.
Evaluation of Concast Bloom Sections for Hot-Piercing Operations . . . H. B. Emerick, Jones & Laughlin Steel Corp.
Effects of Forging and Rolling on Cast Steels . . . C. Wells, Carnegie Institute of Technology
Role of High Strain Rates and Temperature on Deformation and Fracture Characteristics of Fe-C Alloys . . . W. Lawson, T. B. King, N. J. Grant, M.I.T.

Tues. 2:00 p.m.
Vacuum Techniques in Metallurgy—I

Chairmen: W. W. Gullett, Chicago Development Corp.; W. H. Dresher, Union Carbide Nuclear Co.
Arc vs. Electron Beam Melting in High Vacuum Environments . . . R. P. Morgan, T. E. Butler, Union Carbide Metals Co.
Production Applications of Electron Beam Heating to Refractory Metals . . . E. F. Baroch, W. A. Aschoff, Wah Chang Corp.
Use of Electron Beams in Vacuum Metallurgical Process . . . J. C. Simons, P. L. Raymond, National Research Corp.
Purification Techniques for Arc-Melting Ta and W Base Alloys . . . M. L. Torti, C. A. Hornell, National Research Corp.
Furnace Reactions with Gases Which Affect Quality of Vacuum Induction-Melted Uranium . . . R. W. Endebrock, E. L. Foster, Battelle Memorial Institute
Production of Pure Mo and Its Alloys by Floating Zone Melting . . . J. A. Belk, War Office, England

2:00 p.m.
Physical Metallurgy of Refractory Metals—II

Chairmen: E. I. Salkovitz, Department of the Navy; H. R. Ogden, Battelle Memorial Institute
Effect of Purity on Strength of High-

Substructure and Mechanical Properties of Refractory Metals . . . S. Allen, E. M. Passmore, B. S. Lement, Manufacturing Labs.

Flow Characteristics of Zone-Refined Mo Over Temperature Range 4.2° K to 373° K . . . J. Van den Sype, R. Maddin, University of Pennsylvania; A. Lawley, Franklin Institute Laboratories

Flow and Fracture of High-Purity Ta-W Alloys in Ductile-Brittle Transition Region . . . D. P. Ferriss, DuPont Co.; R. M. Rose, J. J. Wulff, M.I.T.

Notch Sensitivity of Refractory Metals . . . A. C. Imgram, F. C. Holden, H. R. Ogden, R. I. Jaffee, Battelle Memorial Institute

Effects of Dispersions on Recrystallization and Ductile-Brittle Transition Behavior of W . . . R. I. Jaffee, B. C. Allen, D. J. Maykuth, Battelle Memorial Institute

Yield and Fracture in Polycrystalline Ta . . . M. A. Adams, Materials Research Corp.

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Production Applications of Electron Beam Heating to Refractory Metals . . . E. F. Baroch, W. A. Aschoff, Wah Chang Corp.

Use of Electron Beams in Vacuum Metallurgical Process . . . J. C. Simons, P. L. Raymond, National Research Corp.

Purification Techniques for Arc-Melting Ta and W Base Alloys . . . M. L. Torti, C. A. Hornell, National Research Corp.

Furnace Reactions with Gases Which Affect Quality of Vacuum Induction-Melted Uranium . . . R. W. Endebrock, E. L. Foster, Battelle Memorial Institute

Production of Pure Mo and Its Alloys by Floating Zone Melting . . . J. A. Belk, War Office, England

2:00 p.m.
Physical Metallurgy of Refractory Metals—II

Chairmen: E. I. Salkovitz, Department of the Navy; H. R. Ogden, Battelle Memorial Institute

Effect of Purity on Strength of High-Fused Salt Oxidation - Reduction Process for Plutonium Fuel Recycle . . . J. G. Reavis, Los Alamos Scientific Laboratory

Recent Developments in ORNL Volatility Process . . . C. E. Guthrie, Oak Ridge National Lab.

Liquid Metal Processing of Fuel From Second Experimental Breeder Reactor . . . R. D. Pierce, L. Burris, Argonne National Lab.

Fluidized Bed in Radioactive Waste Disposal . . . J. I. Stevens, Phillips Petroleum Co.

Wed. 9:00 a.m.
Work Hardening and Strengthening Mechanisms

(Abstract Session)

Chairmen: C. Elbaum, Brown University; R. W. Guard, General Electric Co.

Wed. 9:00 a.m.
Oxidation and Corrosion

(Abstract Session)

Chairmen: C. E. Birchenall, University of Delaware; D. V. Ragone, University of Michigan

Wed. 2:00 p.m.
Nuclear Fuel Reprocessing—II: Foreign and American Developments

Chairmen: J. A. Leary, Los Alamos Scientific Laboratory; G. E. Brand, Atomics International

Thorium Recycle Development . . . D. E. Ferguson, E. D. Arnold, O. C. Dean, W. S. Ernst, Oak Ridge National Laboratory

Scientific Development of the Eurochemic Reprocessing Project . . . R. Rometsch, Eurochemic, Belgium

Reprocessing Fast Reactor Fuels at Dounreay . . . D. M. Donaldson, K. Hartley, P. Lees, N. Parkinson, Atomic Energy Authority, United Kingdom

Recent Developments in Processing Nuclear Fuels by Ion Exchange . . . D. B. James, E. L. Christenson, Los Alamos Scientific Laboratory

Corrosion of Containment Materials by Molten Zn and Cd Alloys . . . J. DeKany, H. Lavendel, L. Burris, Argonne National Laboratory

Corrosion of Materials of Construction for Multipurpose Head-End Equipment in Proposed Fuel Reprocessing Schemes . . . W. E. Clark, Oak Ridge National Lab.

Wed. 2:00 p.m.
Diffusion

(Abstract Session)

Chairmen: R. Baluffi, University of Illinois; H. I. Aaronson, Ford

Wed. 2:00 p.m.
Phase Relationships and Thermodynamics

(Abstract Session)

Chairman: M. N. Nevitt, Argonne National Laboratories

Wed. 2:00 p.m.
Deformation—I

(Abstract Session)

Chairmen: G. F. Bolling, Westinghouse Electric Corp.; J. Brittain, Northwestern University

Thurs. 9:00 a.m.

diography . . . W. D. Kiehle, Eastman Kodak Co.

Magnetic Particle Inspection . . . R. S. Peterson, Sperry Products

Eddy Current Test Methods . . . J. W. Allen, Budd Co.

Mon. 2:00 p.m. Educational Survey

Chairman: R. A. Hamlin, Hamlin Laboratories

Three Possible Approaches to Educational Curriculum for NDT . . . G. N. Beaumariage, Jr., Sacramento State College

Penetrant Inspections . . . R. G. Strother, Magnaflux Corp.

Theory of Ultrasonics . . . P. K. Bloch, Branson Instruments, Inc.

Applications and Interpretations of Ultrasonics . . . W. C. Hitt, Automation Industries, Inc.

Tues. 9:00 a.m.
Military Ordnance and Nondestructive Testing

Methods of Leak Detection for Propellant-Actuated Cartridges . . . W. H. Inglis, Frankford Arsenal

A Primary Ultrasonic Standard . . . J. W. Orner, Watertown Arsenal

Radiography of Cast High Explosives . . . R. A. Youshaw, W. R. Maddy, Naval Ordnance Lab.

Thermographic Profiles of Material Discontinuities . . . D. Wilburn, Ordnance Tank Automotive Command

Ultrasonic Technique for Testing Tires . . . J. Dudzinski, Detroit Arsenal

Radiography of Large, Solid-Propellant Missile Motors With Linear Accelerator . . . J. H. Cusick, H. Heffan, U.S. Naval Ammunition Depot

Tues. 2:00 p.m. Mehl Lecture—

The Need to Know . . . C. H. Hastings, Avco Corp.

Wed. 9:00 a.m.
New Applications of Radiographic Techniques

Neutron Radiography . . . H. Berger, Argonne National Lab.

X-ray Image Enlargement System for Inspection of Missile Case Walls and Weldments . . . R. C. McMaster, Ohio State University

Techniques for Low-Voltage Radiography . . . R. W. McClung, Oak Ridge National Lab.

X-Ray Mass Attenuation Coefficients In the Range 50 to 150 KVP . . . B. E. Foster, J. W. Evans, Oak Ridge National Lab.

Radiographic Behavior of Beryllium and Graphite . . . D. E. Elliott, J. L. Stokes, G. H. Tenney, Los Alamos Lab.

An Image-Intensifier Tube With High Gain for 1-MEV Photons . . . D. T. Green, Picker X-Ray Corp.; W. F. Niklas, Rauland Corp.

Wed. 9:00 a.m.
NDT In the Utilities Industry

Conventional and Nuclear Steam Generating Equipment . . . W. B. Brunn, E. S. Proctor, Combustion Engineering, Inc.

Quality Control in Fabrication of Fuel Element Assemblies for Hallam Nuclear Power Facility . . . B. H. Dixon, Atomics International

Thurs. 1:00 p.m. Enrico Fermi Plant

Aspects of NDT at Enrico Fermi Atomic Power Plant . . . G. L. Parkinson, Power Reactor Development Co.

International Scientific Progress in Field of NDT . . . G. H. Tenney, Los Alamos Scientific Lab.

Reactor Tour and Film (Detroit Edison Co.)

Fri. 9:00 a.m.
Ultrasonics Research and Standards

Ultrasonic Weldment Inspections Currently in Use . . . F. C. Park, Union Carbide Chemicals Co.

Frequency Dependent Effects in Ultrasonic Pulse Flaw Detection . . . J. E. Bobbin, E. A. Henry, Branson Instruments, Inc.

Effects of Test Speed on Ultrasonic Flaw Detection Reliability . . . J. P. Bacon, Elion Ultrasonics, Inc.,

Immersed Ultrasonic Resonance Gaging . . . R. V. Harris, Branson Instruments, Inc.

Ultrasonic Standards for Steel Plate . . . P. Dempsey, U.S. Steel Corp.

Licensing and Proper Use of Isotopes in Industry—Panel
Moderator: G. H. Tenney, Los Alamos Scientific Lab.

Fri. 2:00 p.m.
General Application of Nondestructive Testing

Radiography of Beryllium . . . H. R. Splettstosser, Eastman Kodak Co.

Use of Portable Shear Tester for Testing Adhesive Bonded Joints . . . C. F. Herndon, Convair

Radiography of Steel With 10-Mev Linac . . . S. A. Wenk, Varian Associates

Relation of Fluorescent Penetrant Color to Ambient Illumination . . . J. Kastner, Picker X-Ray Corp.

Evaluation of Penetrant Systems . . . B. Graham, Magnaflux Corp.

Development of Standards for Eddy Current And Ultrasonic Testing of Tubing and Pipe . . . H. J. Bowman, Trent Tube Co.

Special ASM Program

Oct. 27, Cobo Hall

Fri. 9:00 a.m.
Economies in Research & Engineering Through Literature Searching

Viewpoint of the Scientist . . . R. J. Howerton, University of California

Viewpoint of the Engineer . . . D. C. Hilty, Union Carbide Metals Co.

Problems of the Patent Office . . . D. Ladd, Commissioner of Patents

Government Responsibilities . . . G. Abdian, National Science Foundation

American Welding Society Program

Oct. 26, Cobo Hall

Thurs. 9:00 a.m.
New Welding Processes

Electro-Slag Welding . . . W. H.

Metal Powder Industries Federation

Oct. 25, Cobo Hall

Wed. 2:00 p.m.
Powder Metallurgy Symposium

Corrosion Resistant Powder Metallurgy Parts . . . S. Bradbury, Hoeganaes Sponge Iron Corp.

Plastic Impregnation of Powder Metallurgy Parts . . . N. B. Newcomb, National Sinter-Seal Co.

Pre - Alloyed Iron - Nickel Powders . . . N. I. Ananthanarayanan, University of Kansas; R. J. Peavler, Ottowa University

Elevated-Temperature Impact Densification of Mo-UO, Powder Mixtures . . . D. Murphy, R. Kirby, G. Hanks and J. Taub, Los Alamos Scientific Lab.

Application of PMPMA Materials Standard and Specifications Guide for Powder Metallurgy Parts . . . P. J. Failla, Johnson Bronze Co.

Metal Treating Institute

Oct. 26, Cobo Hall

Thurs. 9:00 a.m.
Panel: Can Your Costs Be Reduced by Brazing Techniques?

Moderator: R. F. Gunow, Vac-Hyd Processing Corp.

Hydrogen Brazing of Prototype Stainless Steel Fuel Elements for N.S. Savannah . . . D. C. Dilley, Ferrotherm Co.

Vacuum Furnace Brazing of Stainless Steels . . . T. H. Crane, Kinetics Corp.

Furnace Brazing of Steel Parts with Dissociated Ammonia . . . R. L. Evans, Syracuse Heat Treating

Vacuum Brazing of Aircraft Alloys . . . N. K. Koebel, C. H. Ulbrich, Lindberg Engineering Co.

Salt Bath Brazing of Al . . . F. J. Fahrendorf, Handy and Harman

Brazing Ferrous Alloys to Aluminum . . . R. Seal, D. W. MacVicar, Bi-Braze Corp.

Ultrasonic Manufacturers Association Program

Oct. 26, Cobo Hall

Thurs. 2:00 p.m. Ultrasonics

Transducer Design for Sonic Cleaning Systems . . . L. J. Lyons, Bendix Corp.

Ultrasonic Cleaning and Inspection of Strip . . . H. P. Osterman, Branson Instruments, Inc.

Ultrasonics for Machining . . . G. C. Brown, J. N. Behm, Sheffield Corp.

A New Way To Measure Ultrasonic Cavitation . . . R. E. Heim, Westinghouse Electric Corp.; H. M. Goldsmith, Turco Products, Inc.

American Gas Association

Oct. 24, Cobo Hall

Tues. 2:00 p.m.
New Equipment and Techniques in

Effect of Trace Impurities on Electrical Properties . . . J. E. Kunzler, Bell Telephone Laboratories

Effect of Trace Impurities on Thermoelectric Properties . . . W. P. Pearson, National Research Council, Canada

Electromagnetic Properties of High-Purity Metals . . . W. A. Harrison, General Electric Co.

ASM Technical Program

Oct. 23-26, Cobo Hall

Mon. 9:00 a.m.
Mechanical Properties of Steels

Chairmen: S. L. Gertsman, Dept. of Mines and Technical Surveys and G. H. Enzian, Jones and Laughlin Steel Corp.

Parameters Affecting Fracture Toughness of High-Strength Steel . . . P. M. Lorenz, Boeing Co.

Yield Behavior of Alloy Steels at Low Strain Values . . . G. S. Reichenbach, M.I.T.; D. A. Brown, Stanford Research Institute; P. G. Russell, Alloyd Corp.

Noxious and Innocuous States of Hydrogen in Iron . . . D. J. P. Adenis, Dow Chemical Co.; W. M. Baldwin, Jr., Case Institute

Effect of Temper Brittleness on Dry Friction Wear of Martensitic Steel . . . J. J. Kauzlarich and R. R. Hagglund, Worcester Polytechnic Institute; J. P. Modrak, Rochester Institute of Technology

Repeated Tensile Loading of Iron and Steel . . . C. P. Sullivan, B. L. Averbach, M. Cohen, M.I.T.

Mon. 2:00 p.m.
Steels

Chairmen: J. C. Hamaker, Jr., Vanadium-Alloys Steel Corp. and S. J. Rosenberg, National Bureau of Standards

Effect of Prestraining and Retempering on AISI Type 4340 . . . E. T. Stephenson, Bethlehem Steel Co.; M. Cohen, M.I.T.

Direct Reduction of Ferric Oxide by Solid Carbon in Vacuum . . . T. S. Yun, Seoul National University

Effect of Concurrent Straining on Annealing Behavior of Cold Rolled Vacuum-Melted Electrolytic Iron . . . A. Goldberg, Comision Fulbright De Intercambio Educativo; S. Gourney, U.S. Naval Postgraduate School

Effects of Cb on Properties of Al-Killed, Medium-Carbon Steel . . . E. E. Fletcher, A. R. Elsea, Battelle Memorial Institute; E. C. Bain, Consulting Metallurgist, Sewickley, Pa.

Processing Factors Affecting Magnetic Properties of Low-Carbon Steel . . . D. J. Knight, P. J. Adzema, Jones and Laughlin Steel

Tues. 9:00 a.m.
Carbides in Steels

Chairmen: D. Krashes, Worcester Polytechnic Institute and P. Werner, Westinghouse Research

Fission-Product Systems . . . D. G. Schweitzer, J. R. Weeks, Brookhaven National Lab.

Effects of Alkali Metals on Solubility of U in Bi . . . D. G. Schweitzer, J. R. Weeks, Brookhaven Lab.

Metallographic Studies of Al-Ni-U Bonds in Nuclear Fuel Elements . . . C. L. Angerman, DuPont Co.

Effect of Oxygen on Properties of Zircaloy-2 . . . L. S. Rubenstein, F. L. Shubert, J. G. Goodwin, Westinghouse Electric Corp.

Wed. 2:00 p.m.
Plastic Deformation

Chairmen: R. W. Guard, General Electric Co. and W. A. Backofen, Mass. Institute of Technology

Shear Deformation of Mg and Zn Single Crystals . . . W. L. Phillips, E. I. duPont de Nemours & Co.

Effect of Stress Decreases on Creep of Al in Dislocation Climb Region . . . L. Raymond, W. D. Ludemann, N. Jaffee, J. E. Dorn, U. of Calif.

Investigation of Intermediate Temperature Ductility Minimum in Metals . . . F. N. Rhines, P. J. Wray, University of Florida

Cumulative Fatigue at High Plastic Strains . . . D. E. Gücer, Technical University of Istanbul

Centrifugal Creep Testing on Pure Al . . . D. E. Deutsch, R. S. Carey, J. L. Hull, Aerojet-General

Transient and Destructive Instability in Torsion . . . N. H. Polakowski, S. Mostovoy, Illinois Institute of Technology

Thurs. 9:00 a.m.
Physical Metallurgy

Chairmen: W. R. Upthegrove, University of Oklahoma and R. W. Lindsay, Penn. State U.

Prediction of Atomic Mobility in Metallic Systems . . . O. D. Sherby, Stanford University; M. T. Simnad, General Atomic

New Method for Determination of Liquid-Liquid Equilibria as Applied to Fe-C-Si-Mg System . . . P. K. Trojan, R. A. Flinn, U. of Michigan

Measurement of Interlamellar Spacing of Pearlite . . . B. Gregory, College of Science and Technology; H. T. Hall, G. Bullock, Allmanna Svenska Elektriska Aktiebolaget

Quantitative Metallographic Analysis of Graphite Size in Ductile Cast Iron . . . J. H. Brophy, M.I.T.; M. J. Sinnott, U. of Michigan

Wrought Pb-Cd-Ni Alloys . . . D. N. Williams, K. R. Grube, R. I. Jaffee, Battelle Memorial Institute

Thurs. 9:00 a.m.
Space-Age Metals—I

Chairmen: D. J. Blickwede, Bethlehem Steel Co. and A. R. Kaufmann, Nuclear Metals, Inc.

Effect of Surface Finish on Properties of Be Sheet . . . W. V. Ward, International Nickel Co.; C. O. Matthews, M. I. Jacobson, Lockheed Aircraft Corp.

Bishop, Union Carbide Metals Co.; M. Stern, Linde Co.

Investigation of Effects of Fabrication Variables on Corrosion Resistance of Zircaloy-2 . . . H. S. Kalish, Nuclear Fuel Research Laboratory; H. M. Cobb, Olin Mathieson Chemical Corp.

Propagation of Stress-Corrosion Cracking in Mg Alloy . . . W. M. Pardue, Battelle Memorial Institute; F. H. Beck, M. G. Fontana, Ohio State University

ASM Metals Engineering Program

Oct. 23-26, Cobo Hall

Mon. 9:00 a.m.
Corrosion in Automotive Applications—I

Chairman: R. B. Kropf, International Nickel Co.

Materials for Anti-Smog Devices . . . F. L. LaQue, J. J. Moran, E. N. Skinner, International Nickel

Evaluation of Materials for Automotive Exhaust Systems . . . L. H. Boguski, Republic Steel Corp.

Corrosion Properties of Low Alloy-High Tensile Steels . . . S. K. Coburn, U.S. Steel Corp.

Mon. 2:00 p.m.
Corrosion in Automotive Applications—II

Chairman: F. Bens, Climax Molybdenum Co.

Corrosion in Action (Film) . . . International Nickel Co.

Galvanized Steel for Automotive Use . . . J. C. Widman, Ford Motor

Paint Systems for Corrosion Protection . . . N. Price, C. C. Durbin, Chrysler Corp.

Tues. 9:00 a.m.
Cold Forming of Metals—I

Chairman: R. Sergeson, Jones & Laughlin Steel Corp.

Shear Spinning of Refractory Materials . . . P. P. Crimmins, C. W. Heimlich, Aerojet-General Corp.

Shear Forming of Tungsten Rocket Nozzles . . . J. E. Japka, General Electric Co.

Cold Forming of Stainless Steel . . . G. Vacek, H. M. Harper Co.

Hot Forming of High-Strength Steels . . . R. Blom, Ladish Co.

Tues. 2:00 p.m.
Cold Forming of Metals—II

Chairman: H. N. Bogart, Ford Motor

Cold Forming (Film) . . . National Machine Co.

Steels for Cold Forming . . . J. V. Russell, Republic Steel Corp.

Lubrication for Cold Forming . . . R. W. Perry, Parker Rust Proof Co.

Cold Forming Practices . . . A Braun, Braun Engineering Co.

Wed. 2:00 p.m.
Unusual Metal Removal Techniques

Chairman: D. G. McCullough, General Motors Corp.

and Controls . . . P. Webster, Minneapolis-Honeywell Regulator
Vacuum Furnace Practice . . . R. Korf, Woodward Governor Co.

Metallurgical Society Fall Meeting

Oct. 23-26, Pick-Fort Shelby

Mon. 9:00 a.m.
Protective Coatings and Processing of Refractory Metals

Chairman: E. D. Sayre, General Electric Co., O. O. Srp, Wright Aeronautical Development Div.
Protective Coatings for Tantalum and Its Alloys . . . W. D. Klopp, H. R. Ogden, Battelle Memorial Institute
Development of Oxidation Resistant Coating for Mo . . . P. J. Chao, D. K. Priest, The Pfaudler Co.
Oxidation Resistant Aluminide Coating on Cb Alloy F-48 . . . S. Foldes, General Electric Co.
Properties of Refractory Metals Sprayed Under Controlled Environment . . . M. A. Levinstein, General Electric Co.

Observations on Infiltration of Porous Structures of Mo, W and Their Carbides with Cu in Vacuum and Hydrogen . . . H. H. Hirsch, General Electric Co.
Brazing Alloy Systems for Joining Cb-Base Alloys . . . W. R. Young, E. S. Jones, General Electric Co.

Mon. 9:00 a.m.
Theory of Work Hardening

Chairman: G. M. Pound, Carnegie Institute of Technology
(To be announced) . . . Z. S. Basinski, National Research Council, Canada
(To be announced) . . . J. Lothe, J. P. Hirth, Carnegie Institute

Mon. 9:00 a.m.
Effects of Surface Environment on Strength—I

Chairman: F. N. Rhines, University of Florida
Interaction of Surface and Strength Phenomena . . . E. S. Machlin, Columbia University
Recent British Thin Foil Experiments . . . J. Silcox, Cambridge University
Stresses in Overgrown Films on Crystalline Substrates . . . N. Cabrera, J. H. van der Merwe, University of Virginia
Electromechanical Effect in Semiconductors . . . J. H. Westbrook, General Electric Co.; J. J. Gilman, Brown University
Influence of Thermal-Mechanical History on Embrittlement of Al Alloys by Hg . . . H. Nichols, W. H. Rostoker, Armour Research

Mon. 9:00 a.m.
High-Purity Iron and Its Dilute Solid Solutions—I

Chairman: C. L. McCabe, Carnegie Institute of Technology
L. Kaufman, S. H. Schulman, Columbia University
Effect of Surface on Mechanical Deformation of Metal Single Crystals . . . I. R. Kramer, Martin Co.
Role of Surface on Strength, Ductility and Embrittlement of Metals . . . A. Berghezan, European Research Associates

Mon. 2:00 p.m.
High-Purity Iron and Its Dilute Solid Solutions—II

Chairman: M. Gensamer, Columbia University
Strain-Hardening, Recovery, and Recrystallization of Iron . . . W. C. Leslie, J. T. Michalak, U.S. Steel
Plastic Deformation and Fracture of Iron . . . J. R. Low, Jr., G.E. Co.
Effects of Solute Elements and Other Variables on Yield Stress and Brittle Fracture Stress of Iron . . . N. P. Allen, National Physical Laboratory (England)

Tues. 9:00 a.m.
Continuous Casting

Chairman: C. L. McCabe, Carnegie Institute of Technology; R. Clark, National Forge Co.
Continuous Casting in Europe—Practice and Developments . . . I. M. D. Halliday, United Steel Companies, England
Progress in Continuous Casting of Stainless Steel Slabs . . . L. Nemethy, E. Stock, W. B. F. McKay, Atlas Steels Ltd., Canada
Multiple-Mold Process for Continuous Casting of Steel . . . J. Pearson, British Iron and Steel Research Assoc.; J. Savage, Continuous Casting Co., Ltd, England

Tues. 9:00 a.m.
Effects of Surface and Environment on Strength—III

Chairman: J. J. Gilman, Brown University
Effects of Absorbed Polar Molecules on Etching and Yielding Behavior of LiF Crystals . . . A. R. C. Westwood, Research Institute for Advanced Studies
Effect of Surface Condition on Mechanical Properties of Polycrystalline Ionic Solids . . . R. J. Stokes, Minneapolis - Honeywell
Effect of Controlled Surface Contamination on Ductility of Ionic Crystals . . . G. T. Murray, Materials Research Corp.
Effect of Environment on High-Temperature Strength of Metals . . . M. R. Achter, U.S. Naval Research Laboratory
Effects of Elastic Strain and Environment on Surface Free Energy of Solid Cu . . . S. Floreen, D. V. Ragone, E. E. Hucke, University of Michigan

Tues. 9:00 a.m.
Physical Metallurgy of Refractory Metals—I

Chairmen: J. Maltz, Department of the Navy; J. H. Bechtold, Westinghouse Electric Corp.
Dislocation Substructure in Ta and W . . . S. Weissmann, Y. Nakayama, Rutgers University
R. W. Endebrock, E. L. Foster, Battelle Memorial Institute
Production of Pure Mo and Its Alloys by Floating Zone Melting . . . J. A. Belk, War Office, England

2:00 p.m.
Physical Metallurgy of Refractory Metals—II

Chairmen: E. I. Salkovitz, Department of the Navy; H. R. Ogden, Battelle Memorial Institute
Effect of Purity on Strength of High-Purity W at Elevated Temperatures . . . J. L. Orehotsky, General Telephone and Electronics Labs.
Effects of Interstitials on Properties of Cb-Rich Alloys in Cb-W-Zr Systems . . . J. W. Clark, General Electric Co.
Strengthening of Mo-Ti-Zr Alloys With C and B . . . M. Semchyshen, R. Q. Barr, Climax Molybdenum
Effect of Heat Treatment and Precipitation Hardening on Strength Properties of Mo-Base Alloys . . . W. H. Chang, L. P. Jahnke, General Electric Co.
Effect of Yttrium and Selected Rare-Earth Additions on Removal of Interstitials from W and Mo . . . D. T. Klodt, J. F. Nachman, University of Denver
Physical and Mechanical Properties of a Cr-Base Alloy . . . R. E. Cairns, New England Materials Laboratory; N. J. Grant, M.I.T.
Electron Metallographic Techniques for Studying W Wires and Powders . . . C. F. Tufts, General Telephone and Electronics Labs.

Wed. 9:00 a.m.
Vacuum Techniques in Metallurgy—II

Chairmen: R. G. Jones, Wah Chang Corp.; W. A. Krivsky, Brush Beryllium Corp.
Zone Purification of Yttrium . . . W. C. Necker, General Electric Co.
Separation of Sulphides by Vacuum Distillation . . . C. N. Banks, R. A. Campbell, R. R. Rogers, Canadian Department of Mines and Technical Survey
Status of Vacuum Methods of Gas Analysis for Oxygen, Nitrogen, and Hydrogen in Metals . . . N. A. Gokcen, Aerospace Corp.
Brazing and Heat Treating in Vacuum . . . R. F. Gunow, C. Stitzlein, Vac-Hyd Processing Corp.
Developments in Oil Diffusion Pump Design for Vacuum Metallurgy . . . M. H. Hablanian, National Research Corp.

Wed. 9:00 a.m.
Nuclear Fuel Reprocessing—I: Pyroprocessing

Chairmen: W. D. Wilkinson, Argonne National Laboratory; R. E. Grace, Purdue University
Phase Relations in Plutonium Halide Binary Fused Salt Systems . . . J. A. Leary, K. W. R. Johnson, Los Alamos Scientific Laboratory
Processing of Uranium Dioxide Fuel by Salt Cycle Process . . . K. M. Harmon, General Electric Co.

R. W. Endebrock, E. L. Foster, Battelle Memorial Institute

Production of Pure Mo and Its Alloys by Floating Zone Melting . . . J. A. Belk, War Office, England

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Strengthening of Mo-Ti-Zr Alloys With C and B . . . M. Semchyshen, R. Q. Barr, Climax Molybdenum

Effect of Heat Treatment and Precipitation Hardening on Strength Properties of Mo-Base Alloys . . . W. H. Chang, L. P. Jahnke, General Electric Co.

Effect of Yttrium and Selected Rare-Earth Additions on Removal of Interstitials from W and Mo . . . D. T. Klodt, J. F. Nachman, University of Denver

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Brazing and Heat Treating in Vacuum . . . R. F. Gunow, C. Stitzlein, Vac-Hyd Processing Corp.

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Processing of Uranium Dioxide Fuel by Salt Cycle Process . . . K. M. Harmon, General Electric Co.

Thermodynamics
(Abstract Session)
Chairman: M. N. Nevitt, Argonne National Laboratories

Wed. 2:00 p.m.
Deformation—I
(Abstract Session)
Chairmen: G. F. Bolling, Westinghouse Electric Corp.; J. Brittain, Northwestern University

Thurs. 9:00 a.m.
Deformation—II
Chairman: A. McEvily, Ford Motor

Thurs. 9:00 a.m.
Phase Transformation and Pressure Effects
(Abstract Session)
Chairmen: G. Speich, U.S. Steel Corp.; J. W. Spretnak, Ohio State University

Thurs. 9:00 a.m.
Surfaces
(Abstract Session)
Chairmen: J. P. Hirth, Ohio State University; W. D. Robertson, Yale

Thurs. 9:00 a.m.
Recrystallization, Grain Growth, and Textures
(Abstract Session)
Chairmen: J. W. Rutter, General Electric Co.; R. Richman, Ford

Thurs. 2:00 p.m.
Solidification
(Abstract Session)
Chairmen: R. S. Wagner, Bell Telephone Laboratories; H. W. Weart, Cornell University

Thurs. 2:00 p.m.
Precipitation and Ageing
(Abstract Session)
Chairman: J. B. Clark, Ford Motor

Thurs. 2:00 p.m.
Structure and Properties
(Abstract Session)
Chairmen: J. C. Shyne, Stanford University; W. L. Grube, General Motors Research Laboratory

Thurs. 2:00 p.m.
Powder Metallurgy and Processing of Metals
(Abstract Session)
Chairmen: M. Semchyshen, Climax Molybdenum Co.; J. Wulff, Mass. Institute of Technology

SNT Technical Program

Oct. 23-27, Cobo Hall

Mon. 9:00 a.m. Educational Survey

Chairman: D. W. Ballard, Sandia Corp.

Welcome: R. B. Oliver, Aerojet-General Corp.; National President, SNT

Orientation and Scope of Present NDT Field . . . D. W. Ballard, Sandia Corp.

Radiography, Including Isotope Ra-High Gain for 1-MEV Photons . . . D. T. Green, Picker X-Ray Corp.; W. F. Niklas, Rauland Corp.

Wed. 9:00 a.m.
NDT In the Utilities Industry

Conventional and Nuclear Steam Generating Equipment . . . W. B. Brunn, E. S. Proctor, Combustion Engineering, Inc.

Quality Control in Fabrication of Fuel Element Assemblies for Hallam Nuclear Power Facility . . . B. H. Dixon, Atomics International

Realistic Inspection of Power Plant Components to Reduce Service Failures . . . H. Thielsch, Grinnel Co.

Inspection of Turbine Generator Parts During Manufacture and After Service . . . D. L. Sauer, R. G. Matters, Allis-Chalmers Mfg. Co.

Wed. 2:00 p.m.
Electrical and Magnetic Techniques

Disturbance of Magnetic Fields by Discontinuities in Thin-Wall Steel Tubes . . . F. E. Brammer, W. C. Harmon, Republic Steel Corp.

Eddy Current Testing of Tubular Steel Products . . . H. N. Nerwin, Magnaflux Corp.

Eddy Current Inspection—Compilation of Case Histories . . . J. P. Scheuer, General Electric Co.

New Eddy Current Techniques . . . R. L. Brown, H. L. Libby, General Electric Co.

Controlling Eddy Current Testing of Tubing . . . R. C. Barry, Westinghouse Electric Co.

Eddy Current Testing in the Petroleum Industry . . . P. L. Datt, T. R. Schmidt, Shell Development Co.

Wed. 2:00 p.m.
NDT In the Utilities Industry

Testing of a Maintenance Tool for Power Plants . . . T. D. Carr, R. H. Zong, Philadelphia Electric

Nondestructive Testing Methods for Metallurgical Analysis . . . J. A. Klapper, Ebasco Services, Inc.

Latest Nondestructive Testing Equipment and Techniques Used in Power and Nuclear Plants . . . (By various manufacturers)

Panel Discussion on Nondestructive Testing Problems

Thurs. 9:00 a.m.
Transportation and Nondestructive Testing

NDT in the Auto Industry . . . R. B. Allured, General Motors Corp.

Electronic Audit Gage . . . W. Gross, Performance Measurements Co.

Use of Radioactive Tracers to Study Piston Ring Wear in Locomotive Diesel Engines . . . A. S. Pedrick, Southern Pacific Co.

Density Tests on Concrete Using Gamma Irradiation . . . R. M. Jefferson, Sandia Corp.

NDT in Rubber Tire Industry . . . G. H. Halsey, General Tire and Rubber Co.

Information Centers' Role as Possible Technical Communication Media for NDT . . . M. J. Wahll, Battelle Memorial Institute

G. Abdian, National Science Foundation

American Welding Society Program

Oct. 26, Cobo Hall

Thurs. 9:00 a.m.
New Welding Processes

Electro-Slag Welding . . . W. H. Wooding, Arcos Corp.
Applications of Electron-Beam Welding . . . E. A. Franco-Ferreira, Oak Ridge National Laboratory
Developments in Friction Welding . . . M. B. Hollander, American Machine & Foundry

Thurs. 2:00 p.m.
Gas-Shielded Welding Processes

Survey and Classification of Gas-Shielded Metal-Arc Welding . . . P. J. Rieppel, Battelle
Modern Uses of CO_2 in Gas-Shielded Arc Welding . . . W. B. Blackburn, International Harvester Co.
Gas-Metal Arc, Arc-Spot and Continuous Welding of CRS Sheet . . . T. W. Shearer, Fisher Body Div.

Industrial Heating Equipment Association

Oct. 24, Cobo Hall

Tues. 9:00 a.m.
Industrial Oven Applications in Metal Processing

Metal Processing . . . J. W. Cornelius, DeVilbiss Co.
Continuous Galvanizing . . . F. Sandborn, Industrial Ovens, Inc.
Coating Continuous Strip . . . A. S. Dawe, J. O. Ross Engineering Div.
Heat Treating Aluminum . . . A. J. Snow, W. S. Rockwell Co.

Ultrasonics for Machining . . . G. C. Brown, J. N. Behm, Sheffield Corp.
A New Way To Measure Ultrasonic Cavitation . . . R. E. Heim, Westinghouse Electric Corp.; H. M. Goldsmith, Turco Products, Inc.

American Gas Association

Oct. 24, Cobo Hall

Tues. 2:00 p.m.
New Equipment and Techniques in Melting and Heat Treatment

Solving Heat Transfer Problems by Thermolog . . . R. LaNeay, Selas
Convection—Its Purposes and Principles . . . J. Huebler, Surface Combustion Div.

Special Libraries Association—Metals Division

Oct. 26-27, Cobo Hall

Thurs. 2:00 p.m.
Development of Metals in Autos

Chairman: E. B. Gibson, Carrier Corp.
Microstructure and Material Properties . . . C. W. Phillips, Ford Motor
A Metallurgist's View of the Automobile . . . J. Holsworth, General Motors Corp.
Reliable Metals for Reliable Cars . . . R. Smith, A-C Spark Plug Div.

Fri. 9:00 a.m.

Tour of Scientific Laboratory, Ford Motor Co.

Fri. 12:00 noon, Dearborn Inn

The Past, Present, and Future of Man-Made Diamonds . . . R. W. Guard, General Electric Co.

Fri. 2:00 p.m.

Tour of Ford Motor Co.'s "Hurricane Road" Wind Tunnel and Vehicle Testing Area

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☐ Instruments
☐ Misc. Mfg. Industries (metal)

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An outstanding Metal Show with many innovations awaits you in Detroit this year. For the first time all ASM technical sessions as well as the exhibits will be under one roof at Cobo Hall. For the first time a Materials Application Center – a technical and educational pavillion displaying a wide range of metal products and interesting applications – will be sponsored by ASM. And for the first time in over ten years, the Show will be held in dynamic Detroit, a great metalworking metropolis.

In sponsoring this annual Metal Congress and Exposition, ASM makes available to you an educational experience in metal selection, processing and fabrication that is second to none. Nowhere else in the world will you find such an ambitious presentation of educational lectures and exhibits on the technical aspects of the metalworking industry.

In addition to ASM's extensive program this year, the engineering and scientific sessions of the Congress will include the programs of nine participating societies. A four-day metals engineering program will offer sessions on corrosion of automotive parts, new metal removal techniques, nonmetallic materials, and light metals. The Seminar this year will explore in detail the important subject of ultrahigh-purity metals and ASM's five-day scientific program will range in subject matter from structure and properties of steel, corrosion and physical metallurgy to nuclear and space-age metals. Two other special programs will be sponsored by ASM – one on vacuum techniques in metallurgy and another entitled "Economics in Research and Engineering Through Literature Searching".

The Metallurgical Society of AIME is planning a full program, featuring sessions on "Breakdown of Cast Structures" and "Continuous Casting". Other subjects of interest include refractory metals, high-purity iron, nuclear fuel reprocessing, and theory of work hardening.

The Society for Nondestructive Testing is presenting a five-day program covering radiographic, electrical and magnetic techniques, as well as applications for nondestructive testing in military ordnance and in research. The American Welding Society is cooperating in a program which will discuss new welding processes and review gas-shielded welding. The Metal Treating Institute will have a panel discussion "Can Your Costs be Reduced by Brazing Techniques?" and the Ultrasonic Manufacturers Association will discuss ultrasonics in cleaning and machining operations.

A newcomer to the Congress, American Gas Association, is sponsoring "New Equipment and Techniques in Melting and Heat Treatment" and the Metal Powder Industries Federation symposium – which includes papers on corrosion-resistant powder metallurgy parts and plastic impregnation – should prove most interesting. As part of the Special Libraries Association program, a series of talks on "Development of Metals in Automobiles" will be presented.

A continuing effort is being made to make the Metal Show more and more useful to you and to the metalworking industry. We expect more than 30,000 visitors, all of whom will surely benefit directly from this excellent Congress and Exposition. I would like to invite you personally to attend and partake of this outstanding array of new engineering technology.

William A. Pennington

PRESIDENT
AMERICAN SOCIETY FOR METALS

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Presentations of more than 200 papers provide a comprehensive source for latest information on technical metalworking. Hours: 9:00 a.m. and 2:00 p.m. See program for details.

SHOW HOURS

Monday, Oct. 23	10 a.m. to 6:00 p.m.
Tuesday, Oct. 24	10 a.m. to 9:30 p.m.
Wednesday, Oct. 25	10 a.m. to 9:30 p.m.
Thursday, Oct. 26	10 a.m. to 6:00 p.m.
Friday, Oct. 27	10 a.m. to 5:00 p.m.

43rd National Metal Congress and Exposition

Detroit, Cobo Hall, Oct. 21 through 27, 1961

American Society for Metals ..... **Headquarters, Statler Hilton**

Seminar on Ultra-High Purity Metals, Saturday and Sunday, Hotel Statler
Technical Session, Monday morning through Thursday afternoon, Cobo Hall
Metals Engineering Program, Monday morning through Thursday afternoon, Cobo Hall
"Economies in Research and Engineering Through Literature Searching", Friday morning, Cobo Hall
Symposium, "Vacuum Techniques in Metallurgy", Monday afternoon, Cobo Hall
Awards Dinner, Monday evening, Statler Hotel
Annual Meeting and Campbell Memorial Lecture, Wednesday morning, Cobo Hall
Annual Banquet, Thursday evening, Statler Hotel
National Metal Exposition, Monday through Friday, Cobo Hall
Metallurgy-Ceramics Foundation Session, Monday afternoon, Cobo Hall
Joint ASM-AIME Session on Professional Activities, Sunday evening, Statler Hotel

Fall Meeting of the Metallurgical Society of AIME, sponsored by Institute of Metals Division ..... **Headquarters, Pick-Fort Shelby**

Technical Sessions, Monday morning through Thursday afternoon, Pick-Fort Shelby
Annual Fall Dinner, Tuesday evening, Pick-Fort Shelby

Society for Nondestructive Testing ..... **Headquarters, Henrose Hotel**

Technical Sessions, Monday through Friday, Cobo Hall
Annual Dinner Meeting, Wednesday evening, Henrose Hotel

American Welding Society ..... **(Jointly with ASM)**

Technical Session, Thursday, Cobo Hall

Industrial Heating Equipment Association ..... **(Jointly with ASM)**

Technical Session, Tuesday morning, Cobo Hall

Metal Powder Industries Federation ..... **(Jointly with ASM)**

Technical Session, Wednesday afternoon, Cobo Hall

Metal Treating Institute ..... **(Jointly with ASM)**

Technical Session, Thursday morning, Cobo Hall

Ultrasonic Manufacturers Association ..... **(Jointly with ASM)**

Technical Session, Thursday afternoon, Cobo Hall

American Gas Association ..... **(Jointly with ASM)**

Technical Session, Tuesday afternoon, Cobo Hall

Special Libraries Association, Metals Division ..... **Detroit-Leland Hotel**

Technical Sessions, Thursday and Friday, Cobo Hall
Annual Dinner Meeting, Thursday evening, Cobo Hall

Metal Progress

October 1961 . . . Volume 80, No. 4

COVER: The colorful array of parts on the cover is a striking introduction to our annual Metal Show Issue – this year devoted to special reports which will help you achieve lower production costs through proper metal selection. The cover, painted by DAVID FITCH, was an entry in last year's Metal Progress Cover Contest at the Cleveland Institute of Art.

Technical News in Brief

Columbium Steel Passes Pipeline Test . . . New Equipment Doubles Stainless Steel Capacity . . . Two Columbium Alloys for High-Temperature Applications . . . Silicone Coatings Reduce Scale Formation . . . Survey Reveals Status of Capacitor-Discharge Forming . . . Plasma-Arc Device Deposits Metal Overlays . . . Materials Progress in Organic Adhesives . . . New Aluminum Alloy for High-Strength Welded Structures 13-F

What Metal Shall I Use?

. . . A Special Report to Technical Management in Metalworking

What Steel Shall I Use . . . for Heat Treated Parts in Automobiles, Trucks and Tractors? 66

In today's automotive components, parts to be heat treated are made from a variety of carbon and low-alloy steels. Wide use is also made of selective heating processes for hardening.

What Steel Shall I Use . . . for Heat Treated Parts in Business Machines and Home Appliances? 77

Though manufacturers make many different types of items, heat treatment processes are usually restricted to case-hardening methods because wear resistance is the chief property desired.

The Metallurgist's Role in Selecting Materials for Business Machines, by D. C. Williams 79

When choosing the correct alloy for a stress-bearing part in a business machine, the final decision is generally made through the combined effort of the design engineer and the metallurgist.

What Steel Shall I Use . . . for Nitrided Parts?, by Wilson Leeming 82

As a means of imparting wear resistance at elevated temperatures, nitriding is receiving much consideration. For example, H11 gears for long-time service at 500° F. are now being nitrided.

What Alloy Shall I Use . . . for High-Temperature Applications (Above 1200° F.)?, by Ward F. Simmons 84

Iron, nickel, and cobalt-base superalloys, for applications between 1200 and 1800° F., are likely to remain the only metallic materials for use at high temperatures under oxidizing conditions.

What Refractory Metal Shall I Use . . . for Ultrahigh-Temperature Applications (Above 1800° F.)?, by D. J. Maykuth and H. R. Ogden 92

On the basis of strength, molybdenum alloys appear superior to the other refractory metal alloys up to about 2800° F. At higher temperatures the strength advantage shifts to tungsten alloys. Columbium and tantalum alloys offer superior forming and welding properties and improved low-temperature ductility.

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SUPERTHERM*

Centrifugally cast for 2300°F

End Product is longer life and lower maintenance for heat-resistant parts . . . radiant tubes, furnace rolls, blowpipes, gas generators and other tubular or tubular-section components.

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DETROIT METAL SHOW
OCT. 23-27

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Metal Progress

What Metal Shall I Use . . . for Die Castings? 97

Of the major die casting alloys, those of aluminum are strongest and have the highest thermal and electrical conductivity. Magnesium alloys are lightest; zinc alloys are toughest and have the lowest melting point. Copper alloys are strong and corrosion resistant, but are relatively difficult to cast.

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In selecting materials for high-temperature bearings, engineers must consider the type of environment and the lubricant as well as the maximum temperature that the bearing is to withstand.

What Tool Steel Shall I Use . . . for Applications in Structures and Components? 104

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What Metal Shall I Use . . . for Fabrication of Cryogenic Vessels and Equipment?, by George H. Zenner 110

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What Metal Shall I Use . . . for High-Strength Welded Structures?

Today, as more and more fabricators strive to make their products lighter and stronger, their attention is focusing on high-strength steels and alloys of aluminum and magnesium which can be fabricated into light but strong structures by modern welding techniques.

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Preplated, prepainted and vinyl-laminated metals offer product designers an unlimited choice of colors, textures, patterns and finishes.

What Metal Shall I Use . . . for Resistance-Welded Thermostats?, by Raymond M. Sears 133

To be usable in temperature-controlling devices, bimetallic thermostats must often be welded to other materials.

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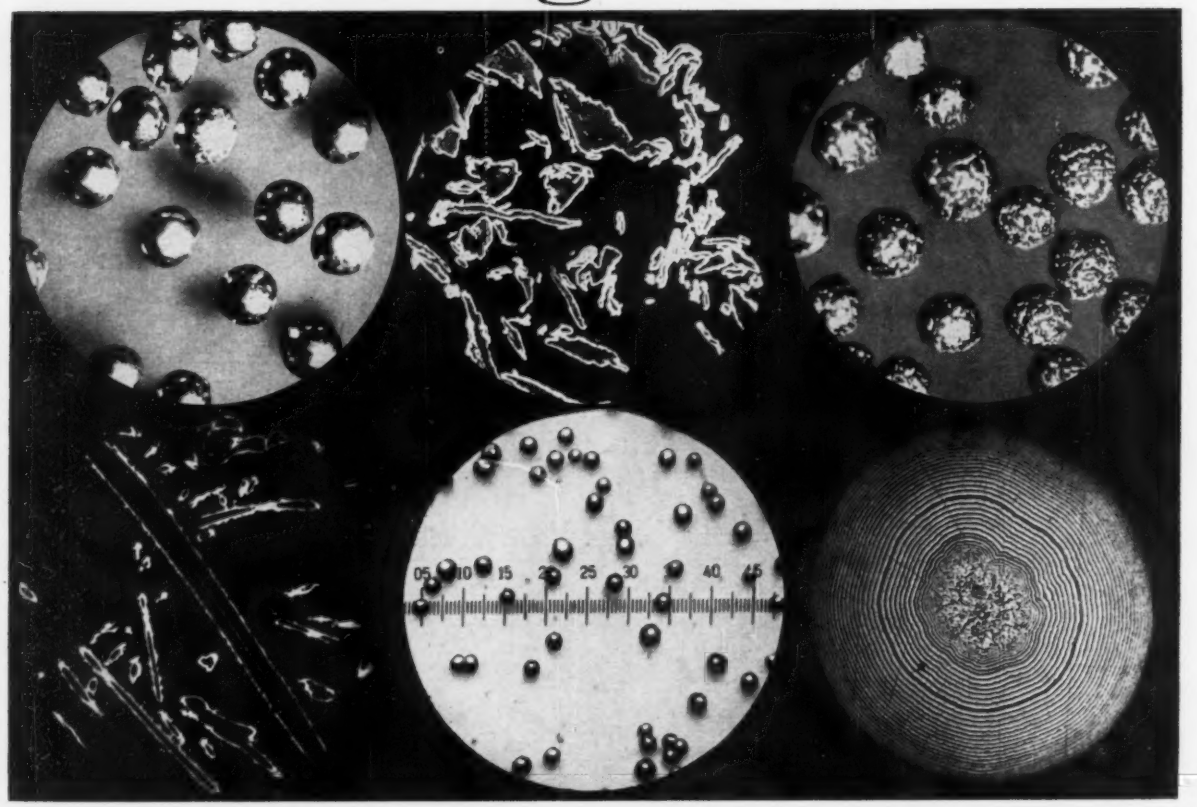
For metallurgists with imagination . . .



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Composite powders—made by Sherritt's patented process—consist of finely divided metal or non-metal particles coated with nickel or cobalt. The composition of these particles can be controlled to produce a wide range of materials with improved or unusual properties.

Composites with metallic cores include nickel-aluminum and nickel-tungsten. Various grades of graphite have been coated with nickel. High phosphorus alloys—not easily formed by conventional methods—are readily prepared with nickel or cobalt as the cladding. Carbides of tungsten, titanium, tantalum, chromium and silicon, and oxides such as alumina, silica, zirconia are used as core materials. Even ceramics and fibrous materials, such as asbestos and alumina-silica wool, have given good results. And, most recent of all, are coated-plastic powders, such as Teflon* coated with nickel.

Applications range from electrical resistance alloys, controlled expansion alloys and hard facing alloys to welding rods, permanent magnets, cemented carbides, bonded abrasive tools, and many others.

How will these metal-coated powders improve *your* processing or your products? What new uses will you make of them? If clad powders spark your imagination—or your curiosity—write our Technical Literature Department for free Booklet, "Metal and Composite Powders." Or, ask a Sherritt Contact Metallurgist to call. Address request to Marketing Division, Sherritt Gordon Mines Ltd., 25 King St. West, Toronto, Canada.

*Du Pont Trademark

SHERRITT GORDON MINES LIMITED

Circle 1491 on Page 48-B

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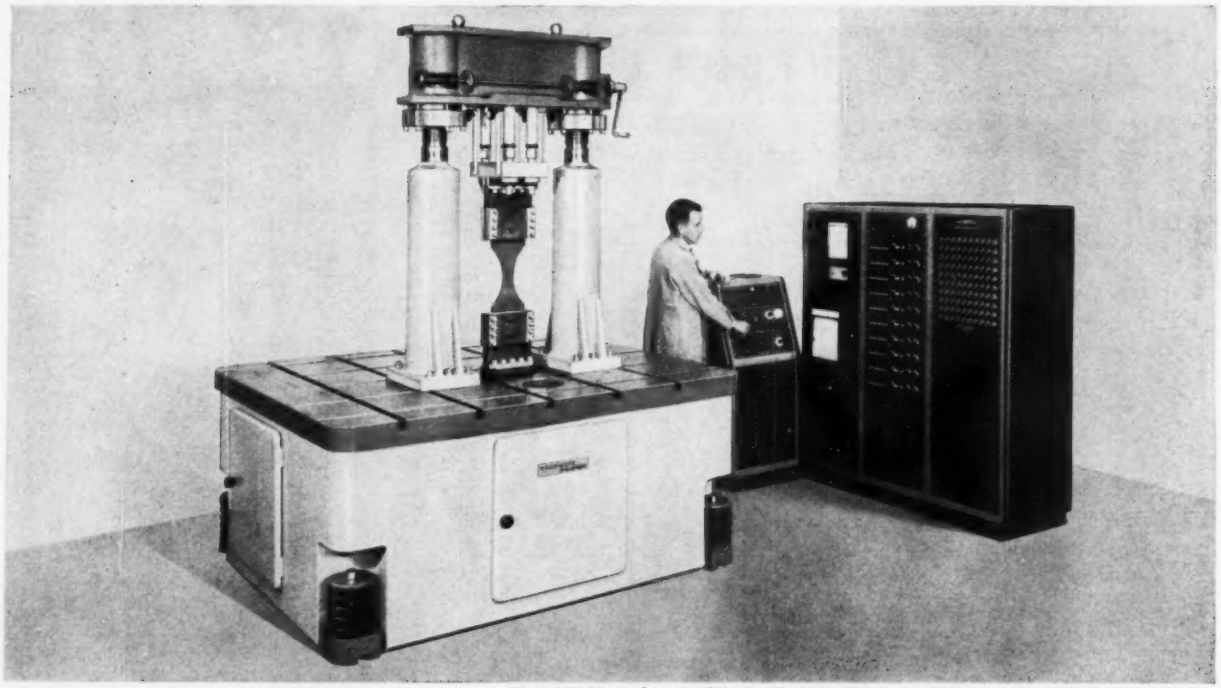
FATIGUE MACHINES BY WIEDEMANN



Model IV-20 equipped with direct stress fixture and Model P-10 Program Controller.

Included among the major products in the recent acquisition by the WIEDEMANN MACHINE COMPANY of the testing machine business from Baldwin-Lima-Hamilton are the complete lines of the well-known, time-proven fatigue machines of the Model SF (Sonntag) and Model IV types. All existing standard models of testing machines and accessory fixtures are now offered by WIEDEMANN.

These versatile testing machines are designed for the testing of materials, machine elements, and structural components in tension, compression, bending, torsion, or combined stresses. They may be used for completely or partially reverse loads or for uni-directional pulsating loads and, within the capacity of the machine, any alternating force may be superimposed over any desired pre-load. They differ basically from the crank-type of fatigue testing machines in that they produce a repeated constant load instead of a repeated constant deflection.

Through the use of fixtures almost any type of stress may be obtained to simulate service conditions. In fact, the usefulness of the WIEDEMANN BALDWIN UNIVERSAL fatigue machines for simulated service test is limited only by the user's ingenuity in designing proper fixtures.

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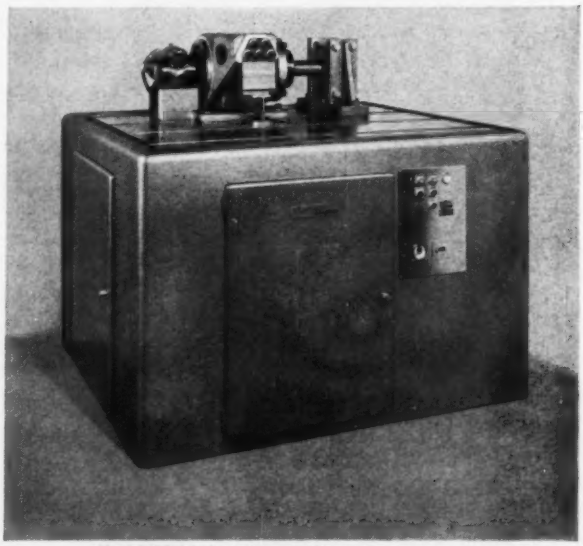

Model SF-10-U equipped with fixture for torsion testing.

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Circle 1493 on Page 48-S

Columbium Steel Passes Pipeline Test

It has been pointed out many times that, by using stronger steels, engineers can often achieve lower fabrication costs; although they may cost more than other grades, less is needed for the same load-carrying ability. This is true not only in large structures such as buildings and bridges but also in pipelines.

A recent example which bears this out is a 47-mile line constructed in Texas by the Natural Gas Pipeline Co. of America. The line is a welded structure of a new columbium-treated steel, called XC-60, which has a guaranteed minimum yield strength of 60,000 psi. It was constructed at a saving of at least $1000 per mile (development costs included) compared with the established average cost for X-52 pipe steel, the strongest grade now in general use in pipelines. About 12% less steel per mile of pipeline was needed. In its 47-mile length, the 20-in. diameter line contains about 6580 tons of steel fabricated of XC-60 plate 0.250 in. thick. If it were made from X-52, it would have required some 7300 tons of 0.281-in. plate. Next use of the new steel will be in a 290-mile line which will be constructed of 30-in. diameter pipe. Savings of more than $4000 per mile are expected.

But a stronger steel is not the only demanding requirement in the pipeline industry. Strength must be accompanied by good weldability, an important factor because the sections must be joined in the field in all kinds of weather. Pipeline steels are carbon grades which rely principally on carbon and manganese additions for increased strength. Unfortunately, these elements cannot be added without making welding more difficult. In the new steel, developed by Great Lakes Steel Corp., Ecorse, Mich., columbium, which has no adverse affect on weldability, is substituted for some of the carbon or manganese that would otherwise be needed to reach a minimum yield strength

WELDER JOINS COLUMBIUM-STEEL PIPE
High-Strength Columbium Steel for Pipelines Need Not Be Preheated

Technical

NEWS

In Brief

of 60,000 psi. High strength is achieved without paying the penalty of poor welding characteristics.

To produce the steel for the 47-mile pipeline, 62 heats were poured. The steel, a semikilled grade contained 0.20 to 0.27% C, 0.89 to 1.28% Mn and 0.006 to 0.018% Cb. Mechanical properties ranged from 65,000 to 83,000 psi. yield, 82,000 to 101,000 psi. tensile and 22 to 32% elongation. Transition temperature, using 50% shear-50% cleavage fracture as a criterion, fell between −34 to 50° F., an improvement over X-52 steel which has exhibited transition temperatures of 20 to 90° F.

Pipe was fabricated at A. O. Smith Corp. by flash welding and mechanical expansion. In burst tests, two 40-ft. lengths of the 20-in. pipe ruptured with 100% ductile shear fractures. Yield point and ultimate strength correlated closely with those obtained during tensile tests on strip.

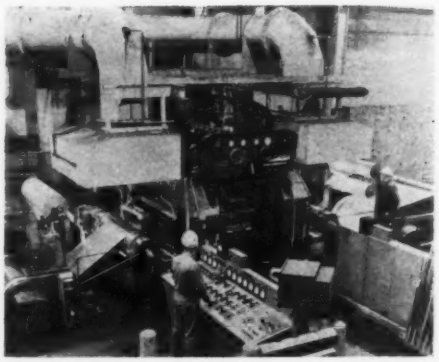
Tests have shown that, when XC-60 pipe is welded in the field, heat input during all passes should be kept to a minimum (particularly during the root pass) and the root gap should be closed to about 1/32 in. These precautions will prevent cracks in the root area and adjacent root bend. The significant difference in welding techniques for X-52 and XC-60 is that the latter requires no preheating. It welds much like mild steel and the weld puddle is more fluid than when X-52 is joined. Radiographic inspection of about 40% of the welds revealed only four defects. No cracks were found.

New Equipment Doubles Stainless Steel Capacity

Speaking recently in Butler, Pa., Logan T. Johnston, president of Armco Steel Corp., cited aluminized steel as an example of "today's specialty; tomorrow's commodity." Equally true of stainless, electrical and other specialty steels, this hint to future progress explains much of the reasoning behind Armco's long-range plans for expansion and improvement which will see close to $250,000,000 being spent for new equipment and plant modernization.

Armco has just completed an $80,000,000 capital-expenditure program at its Butler Works where hot and cold rolled steel, aluminized steel, railroad car wheels and electrical and stainless steels are produced. The mill has doubled its capacity to produce stainless steel.

A new 56-in. hot strip mill, on which any of the steels – from carbon to precipitation-hardening grades – can be rolled, is a key factor in the increased capacity. Other new or modernized equipment includes a 42-in. cold reversing mill for rolling silicon steels at speeds up to 2000 ft. per min., a four-stand, four-high tandem mill, a 52-in. Sendzimir mill (see photo) which can produce stainless strip in gages of 0.010 to 0.125 in. and an anneal and pickle line for stainless.



NEW MILL ROLLS WIDE STAINLESS STRIP
Cold-Rolled Strip Up to 50-In. Wide Can Be Produced in Gages of 0.010 to 0.125 In.

Two Columbium Alloys for High-Temperature Applications

The report on refractory metals which begins on p. 92 points out that these elements – columbium, molybdenum, tantalum and tungsten – and their alloys are the only metallic materials that can be used for large structures above 1800° F. As indicated in the *Metal Progress* Fact Sheet, which accompanies the article, there are a growing number of refractory alloys now available to engineers who are looking for metals to fill their high-temperature needs.

As we went to press, DuPont revealed that it will produce two new columbium alloys. One, known as D-14, is a binary containing 5% Zr; the second, D-36, is a ternary with 10% Ti and 5% Zr.

The binary has a density of 0.310 lb. per cu.in. At room temperature it exhibits a yield strength of 60,000 psi. and an ultimate tensile strength of 75,000 psi. At 2000° F., tensile strength drops to about 30,000 to 32,000 psi. and at 2500° F., it is 12,500 psi. Stress-rupture strength for 100-hr. life is 12,000 psi. at 2000° F. and 5500 psi. at 2200° F.

The ternary alloy, D-36, is somewhat stronger at room temperature where it has a yield strength

Technical

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In Brief

of 70,000 psi. and an ultimate tensile strength of 80,000 psi. When 2000° F. is reached, tensile strength decreases to 23,000 psi.

These alloys are intended primarily for hot surfaces on re-entry vehicles. They are being produced as sheet and coiled strip in widths up to 28 in. wide and as thin as 10 mils and in various shapes, rounds, tubing and wire. Both alloys can be welded by the electron-beam and inert-gas, tungsten-arc processes and resistance seam or spot welded. The ternary, D-36, has an apparent advantage, however, in that it may not need postweld heat treatment to obtain the corrosion resistance required in liquid-metal cooled reactors, a potential application for the alloy.

Silicone Coatings Reduce Scale Formation

One of the practical methods for protecting metal surfaces during heat treatment is to coat them with a silicone fluid. Described previously in *Metal Progress* (see "Surface Coatings Protect Parts During Heat Treatment," *Metal Progress*, June 1961, p. 103), the use of silicones is particularly effective on stainless steels.

As reported in the article, engineers at the Boeing Co., Seattle, Wash., were able to reduce total metal loss on stainless parts to 0.4 to 0.6 mil during three annealing and one descaling operation. The usual loss amounts to about 0.5 to 1.5 mil and descaling is required after each annealing treatment.

Experience at Boeing has shown that one gallon of a silicone, such as Dow Corning 200 Fluid with a viscosity of 50 centistokes, will coat up to 2000 sq.ft. On some alloys, the savings resulting from lower metal losses may be as high as $150. In addition, acid costs are reduced by about $10 and faster production rates can give savings of $50 to $80.

Survey Reveals Status of Capacitor-Discharge Forming

Capacitor-discharge forming, a new high-energy technique for shaping metals, is based on the rapid release of energy (stored in a high-voltage capacitor) through an underwater arc or induction coil. Although it is a promising high-energy process, capacitor-discharge forming has been limited to shaping relatively small tubular and dished parts.

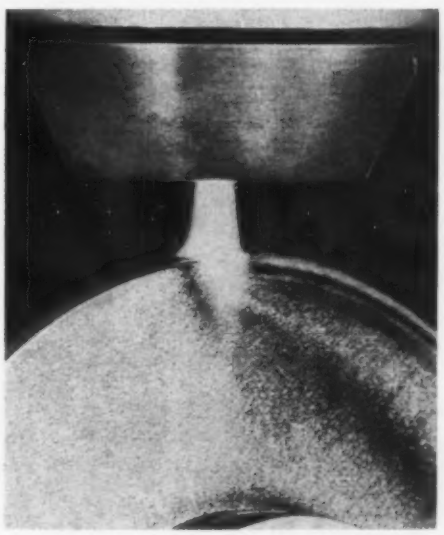
Engineers at Republic Aviation Corp., Farmingdale, L. I., N. Y., who are making a study of the process under an Air Force contract, reveal that parts formed in this country have included 4-in. steel tubes having ⅛-in. walls, sheet metal parts such as a 7-in. diameter dish 3/16-in. thick and 24-in. diameter domes. Most work has been done with aluminum and steel.

Advantages of the process over explosive forming (see the special report in *Metal Progress*, August 1961, p. 66 to 78) are that it can be used in the plant, eliminates storage of explosives, allows repetitive discharges at high rates and can be precisely controlled.

Plasma-Arc Device Deposits Metal Overlays

The plasma arc – probably more familiar to you as a high-speed cutting torch (cutting speeds up to 300 in. per min. can be attained) – is also being used to deposit fully fused overlays for wear and corrosion resistance.

With equipment which will be demonstrated at the A.S.M. National Metal Show in Detroit this month by Linde Co., Div. of Union Carbide Corp., New York, coatings 0.010 in. to 3/16 in. thick are deposited in one pass as a bead ⅛ to 1 in. wide. Penetration of the overlay into the base material



PLASMA-ARC DEPOSITS METAL COATING
Overlays 1/8 to 1 In. Wide and 0.010 to 3/16 In. Deep Can Be Applied

Technical NEWS In Brief

can be held to a minimum of 0.005 in. and the overlay metal or alloy, which is fed through the hot plasma arc as a powder, is deposited at about 6 lb. per hr.

Linde engineers report that any metal or alloy can be used if it is available as a powder. It must, however, have a melting point close to or lower than that of the base metal.

Materials Progress in Organic Adhesives

When adhesives are used for bonding honeycomb structures, they give off gases during the curing process. As a result, each of the cells of the core must be vented. Unfortunately, the vents also permit water to enter the panel and, consequently, aircraft producers have limited their use of bonded sandwich structures.

Recently, however, engineers at Vertol Div. of Boeing Co. in Morton, Pa. announced that they have been using a new polyamid epoxy adhesive which permits them to produce honeycomb panels without the need for vent holes in the core structure.

The adhesive comes in a roll and resembles thin plastic. It is placed between the honeycomb core and the aluminum facing sheets. This package, held together with tack rivets and wrapped in burlap, is then enveloped with a polyethylene bag. After the air is pumped out of the bag, the assembly is heated at 350° F. for 1 hr. to cure the adhesive.

Vertol is now using 75 nonperforated honeycomb assemblies in each of the YHC-1B helicopters it is building for the Army. The aircraft's large fuel pod, floor frames, walkway, rear loading ramps, radio shelves and work platforms are examples. These structures replace heavier riveted stiffeners. They do not need special metal priming and masking operations, humidity-controlled rooms and drying ovens, and can be made faster and at lower cost than riveted structures. The adhesive, produced by Bloomingdale Rubber Co., will make metal-to-metal bonds having a lap shear strength of 7000 psi.

POLYAMID EPOXY BONDS HONEYCOMB PANEL
The Adhesive Gives a Metal-to-Metal Lap Shear Strength of 7000 Psi.

From Here and There

The Copper and Brass Research Assoc. announced that the copper and brass industry has adopted a system of numerical designations for its wrought alloys. More than 100 copper and copper-base alloys will be classified by a three-digit system (example: berylium copper will now be identified as alloy No. 172).

• • •

One of the largest quantities of strontium-90, fabricated at the Oak Ridge National Lab. as pellets and sealed in four Hastelloy C capsules, will be used as a power source for a Navy weather station in the Antarctic. The 40,000-curie source will produce 250 thermal watts which will be converted to about 12 watts of electricity to operate a telemetry unit.

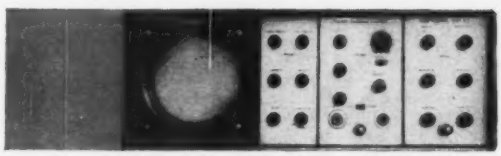
• • •

A process for coating fine wire with uniform crystals of Cb-Sn alloy has been developed by engineers at Radio Corp. of America, New York. Tests indicate that the wire, which can be produced at a rate of 30 ft. per hr., remains superconductive at cryogenic temperatures in magnetic fields of 94,000 gauss while carrying a current of 7 amp.

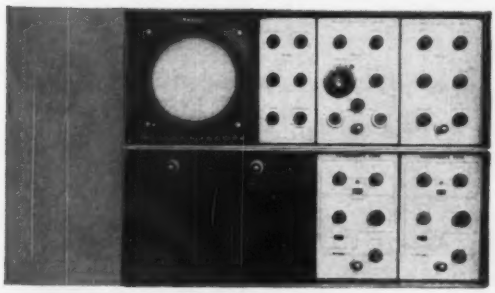
New Aluminum Alloy for High-Strength Welded Structures

Excellent weldability, high weld efficiency, good corrosion resistance, high strength at elevated (450 to 750° F.) and subzero temperatures are significant characteristics of aluminum alloy 2219. These properties and the application of the heat treatable alloy in a welded fuel tank will be described in two articles in *Metal Progress* next month. The articles supplement our first report on 2219 alloy which appeared in the September issue.

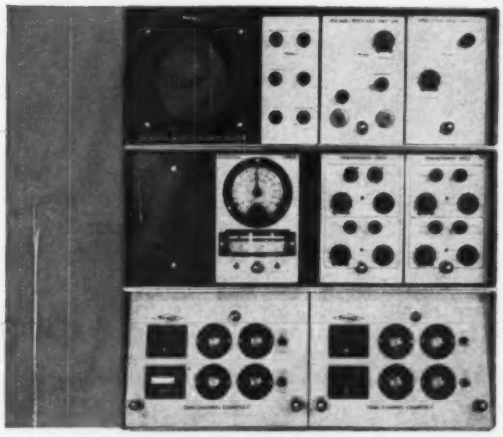
new IN ULTRASONIC TESTING



UM 700 Reflectoscope



UM 700 with special function chassis and two transigates



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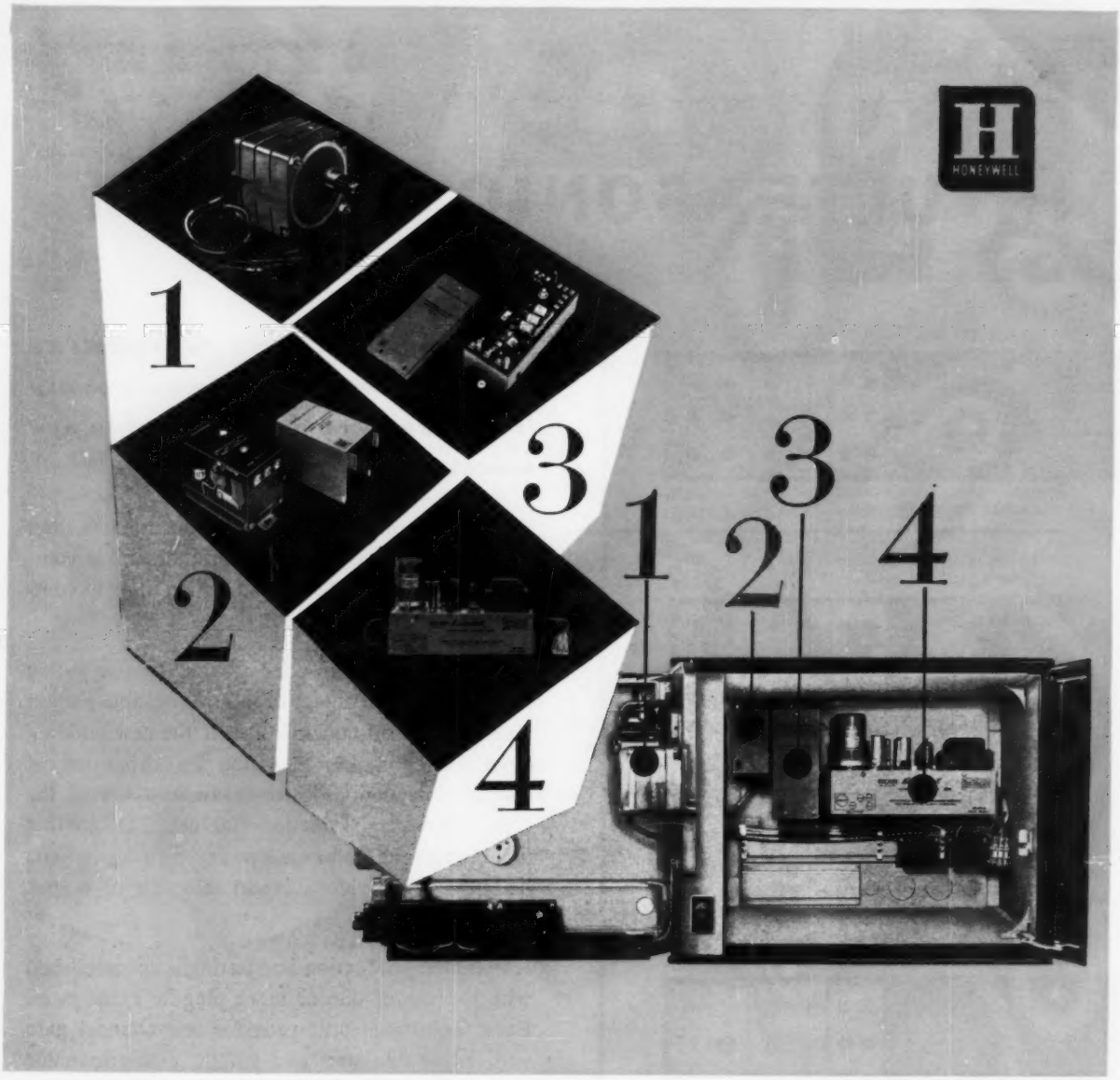

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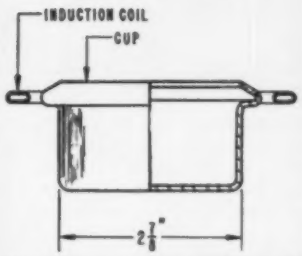

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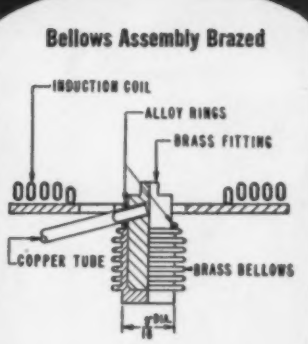

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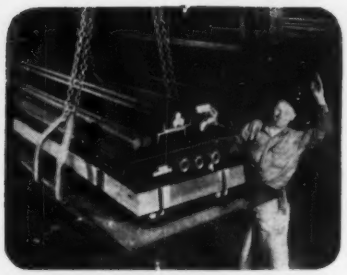

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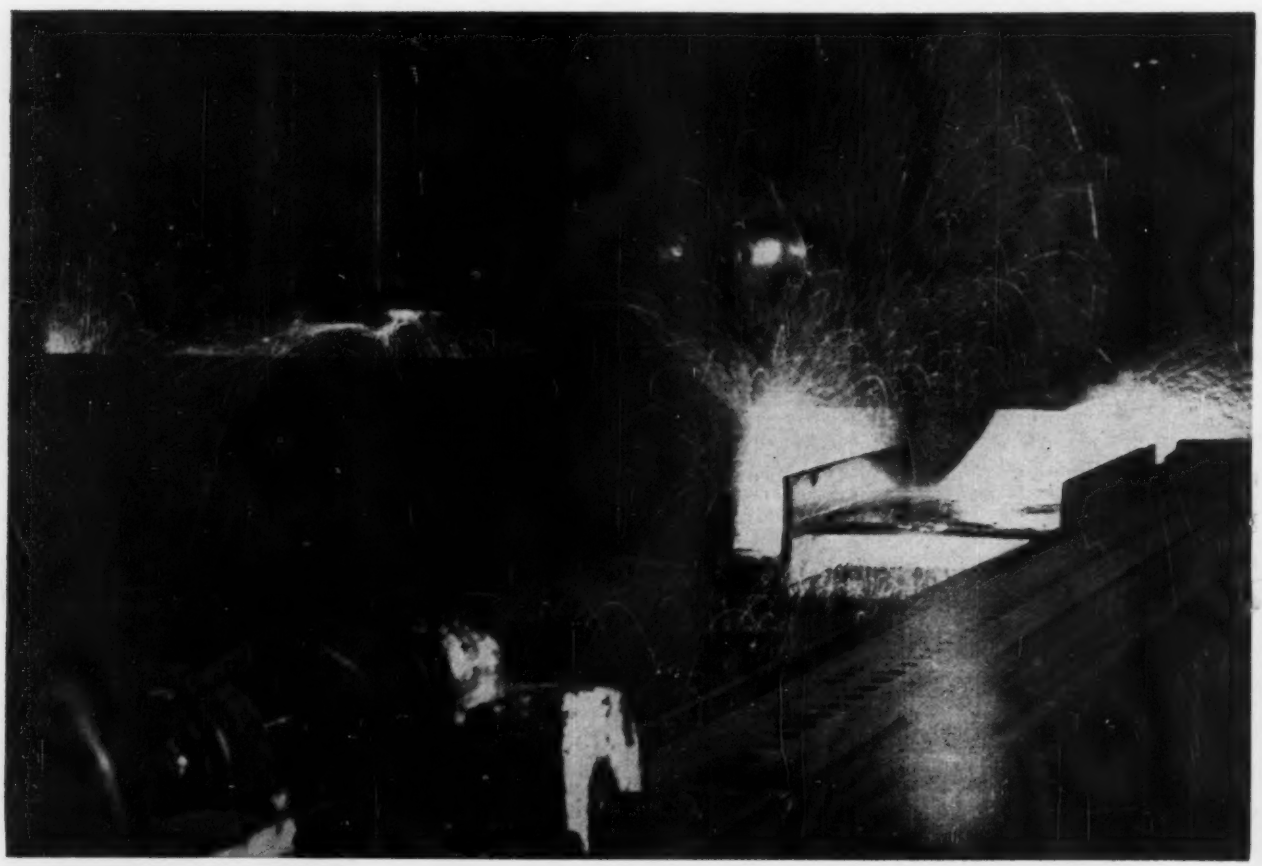
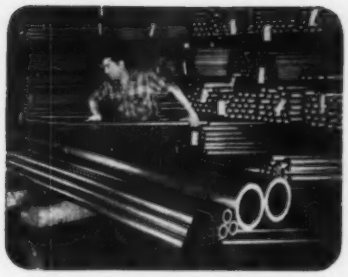
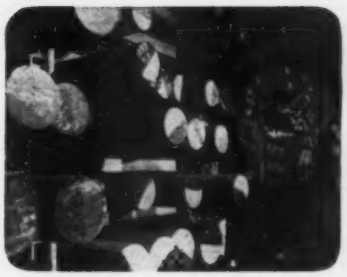
Take a quick tour of Ryerson on these pages, then contact your Ryerson representative for details.

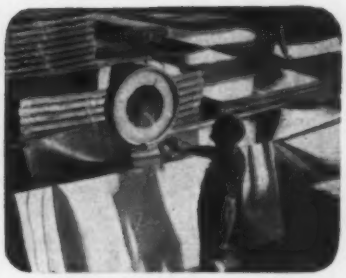




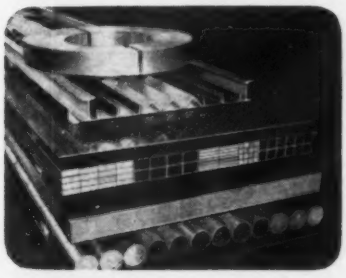
TUBING & CF BARS—Tubing: seamless and welded mechanical; structural; hydraulic cylinder & fluid line; Ledloy® 170. Bars: shafting, machinery steel, accuracy and screw stock, including fast-machining Ledloy 375 and 300.



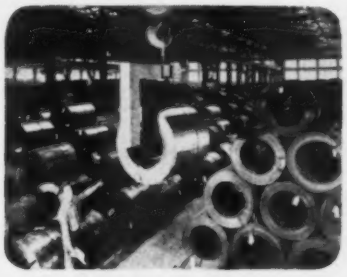
ALLOY STEEL—8-step certified quality program assures riskproof alloys—case-hardening, direct-hardening heat-treated alloys; leaded alloys, including fast-machining Rycut® steels; aircraft quality alloys; etc.



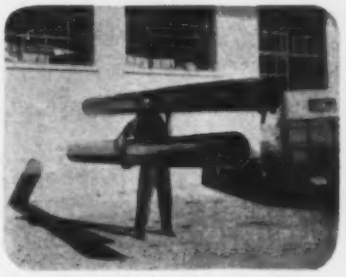
STAINLESS STEEL—2351 sizes, shapes, types and finishes in sheets, plates, bars, tubing, pipe and fittings, etc. All certified to meet ASTM, SAE, military, DuPont or GE specifications. Check in for fast stainless service.



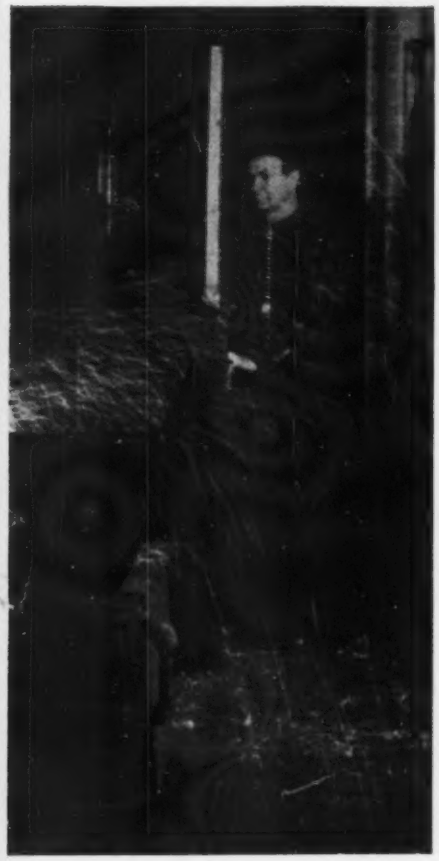
ALUMINUM—Nation-wide service on Reynolds aluminum includes all mill products: sheets, plates, tubing and pipe; wire rod and bar; structural and extruded shapes; construction products for buildings and highways.



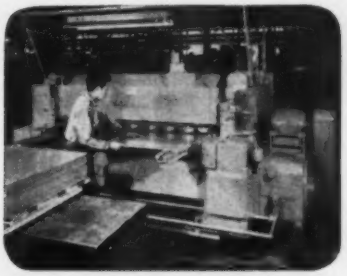
SHEET & STRIP—More than 20 kinds of stock sizes—or we can cut sheets to your order with latest shears, slitters and cut-to-length lines for faster service. Also strip coils, etc. Call us for all your sheet and strip requirements.



INDUSTRIAL PLASTICS—Ryertex-Omicron PVC pipe, tubing, sheet and rod conquer more than 281 corrosives. Also rigid Kralastic and flexible polyethylene pipe and Ryertex® laminated phenolic resin plastics.



This big friction saw bites through a 24" beam in less than 12 seconds. The accuracy of Ryerson cutting on all types of equipment is the closest in the industry.



MACHINERY—More than 3800 types and models of metal-fabricating equipment for bending, braking, drilling, forming, hoisting, pressing, punching, rolling, sawing, shearing, threading and welding.

BE METALOGICAL—All the plus values of our products and service add up to giving you "optimum value for every purchasing dollar. Whatever you need—steel, aluminum, plastics, machinery—be Metalogical, call Ryerson.

RYERSON METALOGICS

JOSEPH T. RYERSON & SON, INC., MEMBER OF THE STEEL FAMILY

STEEL · ALUMINUM · PLASTICS · METALWORKING MACHINERY

Circle 1497 on Page 48-8

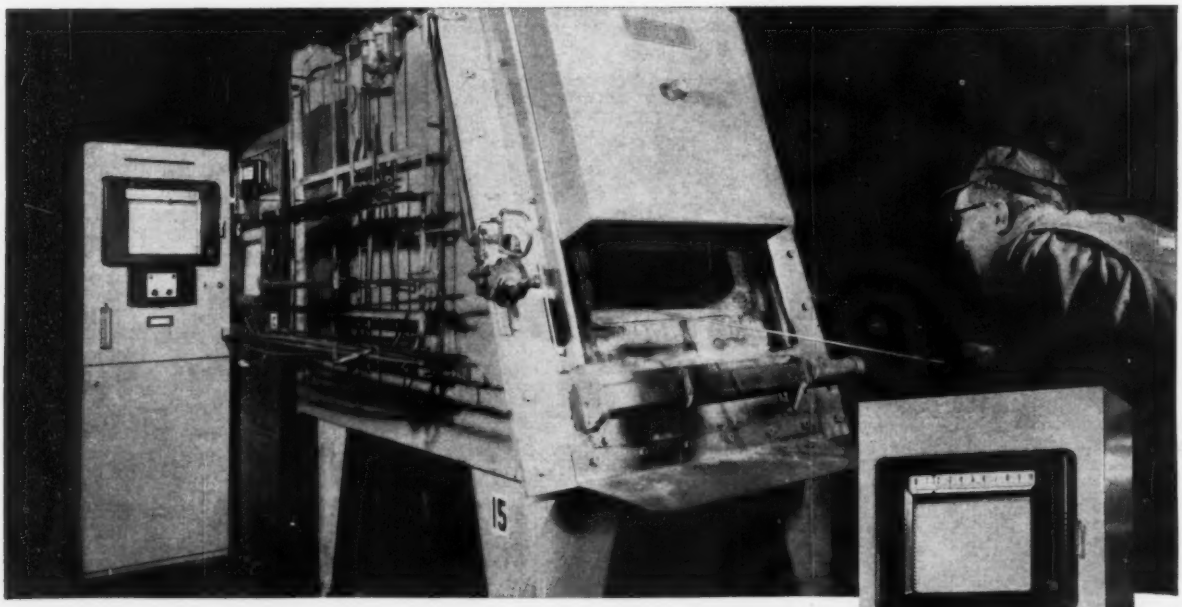
NEW

...through research by Barber-Colman

Model 30D Automatic Dewpoint Controller

INDICATES, RECORDS and CONTROLS

moisture content of protective gas atmospheres



VERSATILE OPERATION

Specially designed for metalworking and packaging processes, Model 30D controls degree of oxidation-reduction and/or carburizing-decarburizing of atmosphere for generators and furnaces.

WIDE DEW POINT RANGE

Model 30D detects and controls dew point in the range of −50°F to +110°F with any select span of 50° F. Assures high control accuracy within ±.5° F.

EASY MAINTENANCE

Vapor state sensor does not condense out moisture sample. This eliminates troublesome refrigeration and reduces contamination. Model 30D requires minimum filter changes . . . inexpensive filter changed in 30 seconds. System incorporates readily accessible, time-proven components.

ULTRA-FAST RESPONSE

A unique sensor design — moisture is not condensed during the continuous detection process. This makes possible a 5-second response speed per 10 ft. of sample line.

LOWER OPERATING COSTS

Low gas flow — 15 cu. ft. per hour sample gas for low waste and fast response. Low power consumption. Model 30D sensor reduces operating costs by eliminating the replenishing of salt procedure.

SIMPLE MODULAR DESIGN

Model 30D features minimum moving parts and maximum design simplicity. Indicating and control section can be remote from sensing unit for centralized control.

Contact Barber-Colman today.

BARBER COLMAN

BARBER-COLMAN COMPANY

Industrial Instruments Division

Dept. V, 1518 Rock Street, Rockford, Illinois, U.S.A.

BARBER-COLMAN of CANADA, Ltd., Dept. V, Toronto & Montreal • Export Agent: Ad. Auriema, Inc., NY.

Circle 1498 on Page 48-B

Stainless Steel Edition

BRAZING STAINLESS STEEL

—How to Make The Most of It

BRAZING NEWS #85

HANDY & HARMAN
General Offices: 850 Third Avenue, New York 22, N.Y.

As a premium-priced alloy, stainless steel warrants every care to insure that the most effective use is made of the metal and that it receives no treatment that will impair its intrinsically superior qualities.

Thus, any method of joining stainless must be compatible with the most efficient and economical design methods and harmonize with the alloy's metallurgical properties and the ultimate use of the fabricated part.

That's where brazing comes to the rescue. Both in fabrication and in use—brazing makes the most of stainless steel.

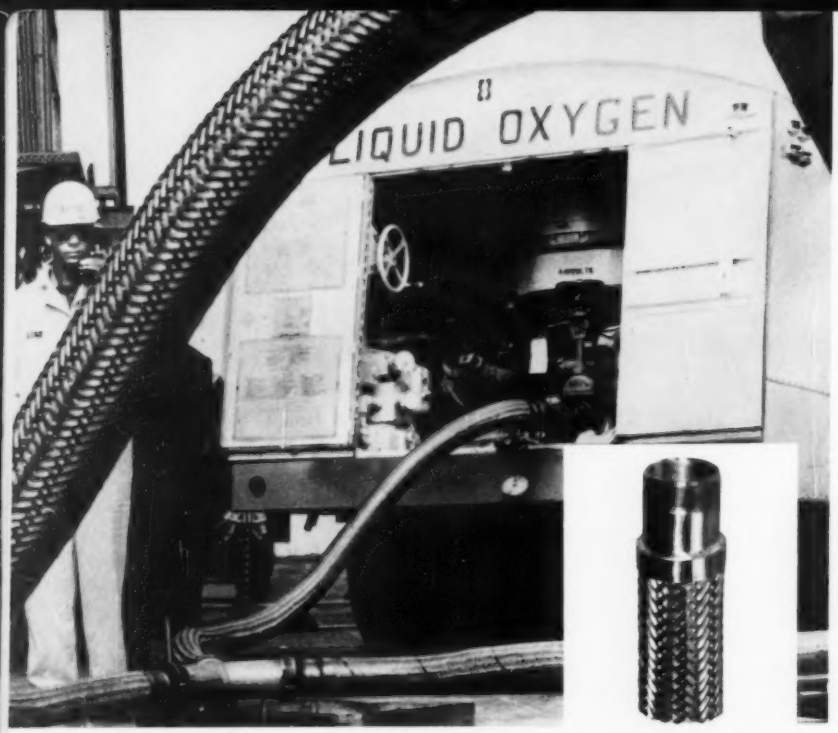
IN FABRICATION

Brazing alloys not only join stainless to itself but also make excellent joints with dissimilar metals. ■ Brazing makes complex joints easily, economically. ■ Brazing is compatible with both thin and heavy components. ■ The speed with which the brazing operation is performed and the relatively low temperatures employed minimize the danger of heat damage encountered with other methods. In certain cases, the method can be used to heat treat and braze at the same time. ■ By utilizing proper control of the brazing cycle and by use of preforms and the proper heating equipment, exact reproducibility of joints can be assured. ■ Brazing makes smooth, neat joints requiring little or no finishing, and allowing no openings for product entrapment.

DURING USE

Stainless steel is usually employed on the basis of one or more of these broad categories:
To serve the overlapping functions of providing fine appearance and excellent corrosion resistance. ■ To withstand heat. ■ To withstand the embrittling effects of very low temperatures. ■ To protect the purity of foods, pharmaceuticals, beverages and similar materials during processing and provide surfaces that can easily be cleaned and sterilized.

Handy & Harman has developed several specialized groups of brazing alloys that assist in maintaining the effectiveness of stainless steel under each of these conditions of service.



A SHOCKING EXPERIENCE —THERMALLY, THAT IS

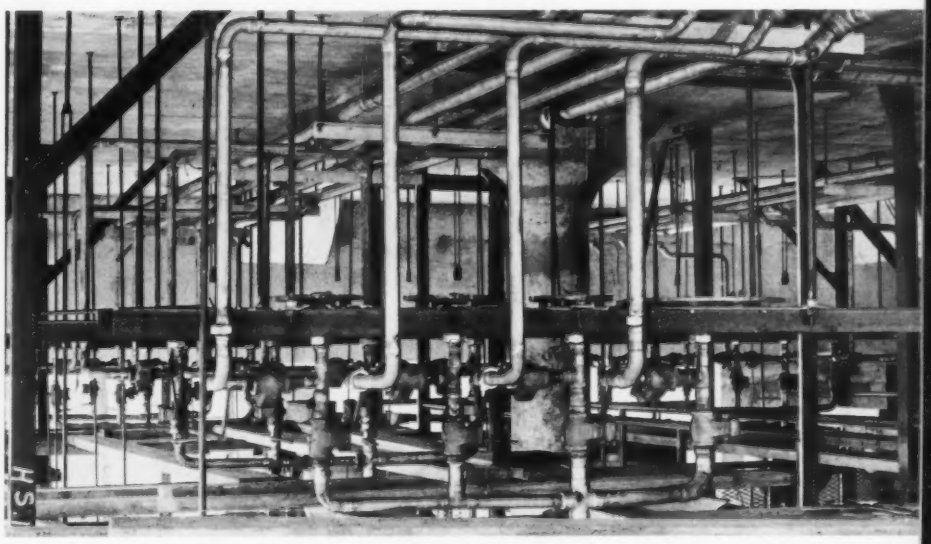
The nearly instantaneous plunge from ambient temperatures of about 100°F to nearly −300°F experienced by this liquid oxygen-carrying hose assembly at one of our missile bases is about as severe an example of thermal shock as you can find. Yet the stainless steel hose, manufactured by Anaconda Metal Hose, takes the punishment with ease. So do the brazed connections made with Handy & Harman EASY-FLO and EASY-FLO 35.

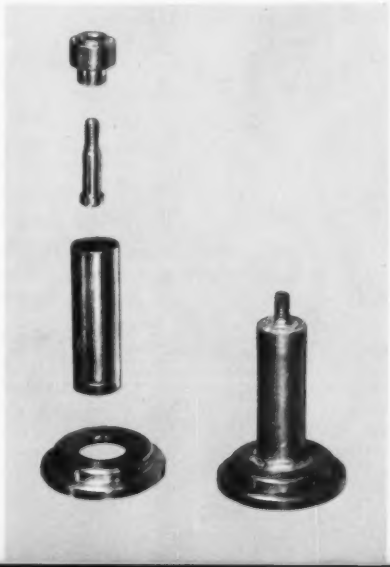
In addition to good cryogenic properties, the fabricator obtains these substantial benefits: higher burst pressure limits, since brazing does not anneal the base metal . . . and the ability to perform joining operations with less equipment and less labor expense than other methods would entail.

HOW BRAZING PROVED A REAL "LIFE SAVER" ON A TUBING PROBLEM

When the LIFESAVER Corporation planned an addition to its plant in Port Chester, N.Y., they decided on stainless steel thin-wall tubing for conveying sugar and corn syrup solutions. Stainless was a logical choice for its ability to protect solution purity and because it was not affected by the fermenting tendency of the sugar.

Joints represented a special problem in that they not only had to exhibit the same good properties as the stainless but also had to exclude the possibility of crevices in which ferment could lodge and breed fungus. Threaded connections were out, of course. Brazing saved the day, providing smooth, strong, crevice-free joints that are also corrosion-resistant and free of contamination tendencies.





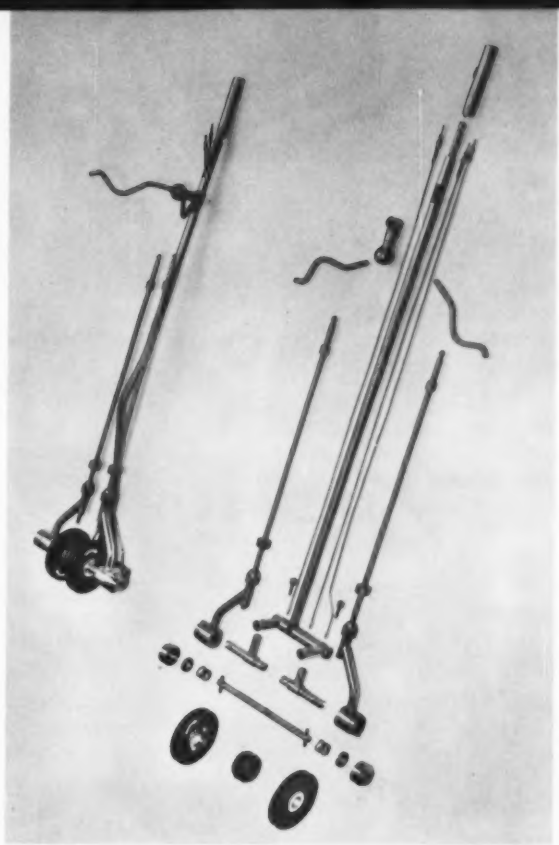
BRAZING— A SIMPLE SOLUTION FOR COMPLEX JOINING PROBLEMS

The ability of brazing to join nearly any variety of dissimilar metals allows the fabricator to build an impressive diversity of properties into a single part. In this bobbin assembly for a gas valve, the plug is made of leaded copper, the screw of Type 446 stainless steel, the tubing of Ambrac copper-nickel-zinc alloy, and the base of Type 303 stainless. Two rings of EASY-FLO 3 join the entire assembly, allowing the fabricator to use stainless selectively—how and where he wants it.

HERE'S SOMETHING YOU CAN GET YOUR TEETH INTO

...And you probably have, many times. This "Dual Arm Transmission," manufactured for dentists by the Super-Donic Manufacturing Company, Atlanta, Ga., is the vital link between the drill and its motive power. Fabricated of small diameter Types 304 and 316 stainless steel tubing, it involves some 17 separately brazed joints.

By Brazing with Handy & Harman BRAZE 630 and Handy Flux Type B-1, the manufacturer gets strong joints that withstand constant vibration and handling, withstand humidity or other corrosive atmospheres and match the color of stainless as well.



IN UNION THERE IS STRENGTH

...Especially when the union is made by brazing. Stainless-clad metals are economically made by Bridgeport Brass to *exact finish gauge* by brazing with Handy & Harman EASY-FLO 45.

This method produces an integral bond that holds firm even under severe conditions of forming and use and is ideal for manufacturing an entire range of products varying in type from the famous Bridgeport Copperware to-heat-exchanger tube sheets. The corrosion resistance and fine appearance of stainless ...the thermal conductivity of copper...the economy of carbon steel...the specialized properties of other metals — all can be easily combined in any combination by brazing.

FILTER KINGS

Nothing less than 100% joint integrity will do for these stainless steel filters, manufactured by Dynamic Filters, Inc., Detroit, Mich. Brazing with EASY-FLO provides it—plus some other highly desirable features. Made by bonding very fine stainless wire mesh to a coarser backing screen, forming to shape and attaching fittings, the filters present a multitude of joints, large and small, that must be completely free of flaws if the units are to perform their task properly. EASY-FLO handles the task with ease—penetrates quickly into small voids and capillary spaces, then solidifies to form strong, neat joints requiring a minimum of finishing. Brazing is compatible with both the fine mesh wire and heavier fittings . . . does not anneal or harm delicate components.

"I Fabricate Stainless For Many Types of Service—

WILL EASY-FLO HANDLE THEM ALL ?"

The choice of a proper brazing alloy depends on a number of factors, including the kind of service to which the stainless steel part will eventually be put. Handy & Harman has developed many specialized alloys each of which is tailored to render maximum life and service in a given set of conditions.

NORMAL INDOOR USE

For many conditions of use, where stainless steel is being used for decorative and appearance reasons, EASY-FLO renders excellent performance and is extremely versatile in joining stainless to itself or to a wide variety of other metals.

WET AND HUMID ENVIRONMENTS

A group of brazing alloys has been developed by Handy & Harman for the specific purpose of preventing interface (crevice) corrosion which can occur when brazed stainless steel joints, particularly in the 400 series, are exposed to constant humidity.

HIGH TEMPERATURE USE

For brazed assemblies that must operate at high temperatures, Handy & Harman produces a whole family of brazing alloys, some of which are suitable for joints exposed to temperatures as high as 1800-2000°F. Each alloy is designed to conform to a specific set of temperature and oxidizing conditions. The choice of alloy depends upon certain fabrication requirements regarding flow, the degree of penetration and solution of the base metal which can be tolerated, and the heating equipment available.

PURITY-SENSITIVE APPLICATIONS

Where stainless steel equipment is to be used in processing or handling foods, pharmaceuticals, beverages or similar products, Handy & Harman cadmium-free brazing alloys are available to help protect products from objectionable metallic contamination.

FLUXES, TOO

Our famous Handy Flux will handle the great majority of stainless brazing jobs you may be called on to perform. However, where brazing involves the formation of particularly refractory oxides or the use of high brazing temperatures or prolonged heating cycles, one of Handy & Harman's specialized fluxes may be preferable.

IF YOU HAVE THE STAINLESS—

We Have The Brazing Materials—And Any Technical Data You Need

If you're fabricating stainless for either a standard line of products or to meet customers' special needs, chances are we can help you get better results. We have a library of information that is at your disposal to help you select the best brazing alloys and fluxes for the job and suggest optimum brazing procedures. Any part of it is yours for the asking. As a start, we suggest you send for our new Brazing Alloy Selection Chart For Stainless Steel. Just write us or check number 1500 on the reader service card. Remember, too, that our Technical Service Staff is available at all times to assist you with brazing problems of any nature.

HANDY & HARMAN

General Offices: 850 Third Avenue • New York 22, N. Y.

Offices and Plants: Bridgeport, Conn. • Chicago, Ill. • Cleveland, Ohio • Dallas, Texas • Detroit, Mich.
Los Angeles, Calif. • Mt. Vernon, N. Y. • Providence, R. I. • Montreal, Canada • Toronto, Canada

Circle 1500 on Page 48-B

You can depend on **Tempilstik°**

temperature indicating crayons

Each batch of Tempilstiks° is certified for melting point by our laboratory — and independently tested for accuracy by a distinguished firm of metallurgical chemists.

A PRODUCT OF AMERICAN INGENUITY

Tempilstiks° have earned an enviable acceptance as one of the standard methods of determining temperatures—in both science and industry. This gratifying position is the result of many years of accumulated know-how and unremitting research and development.

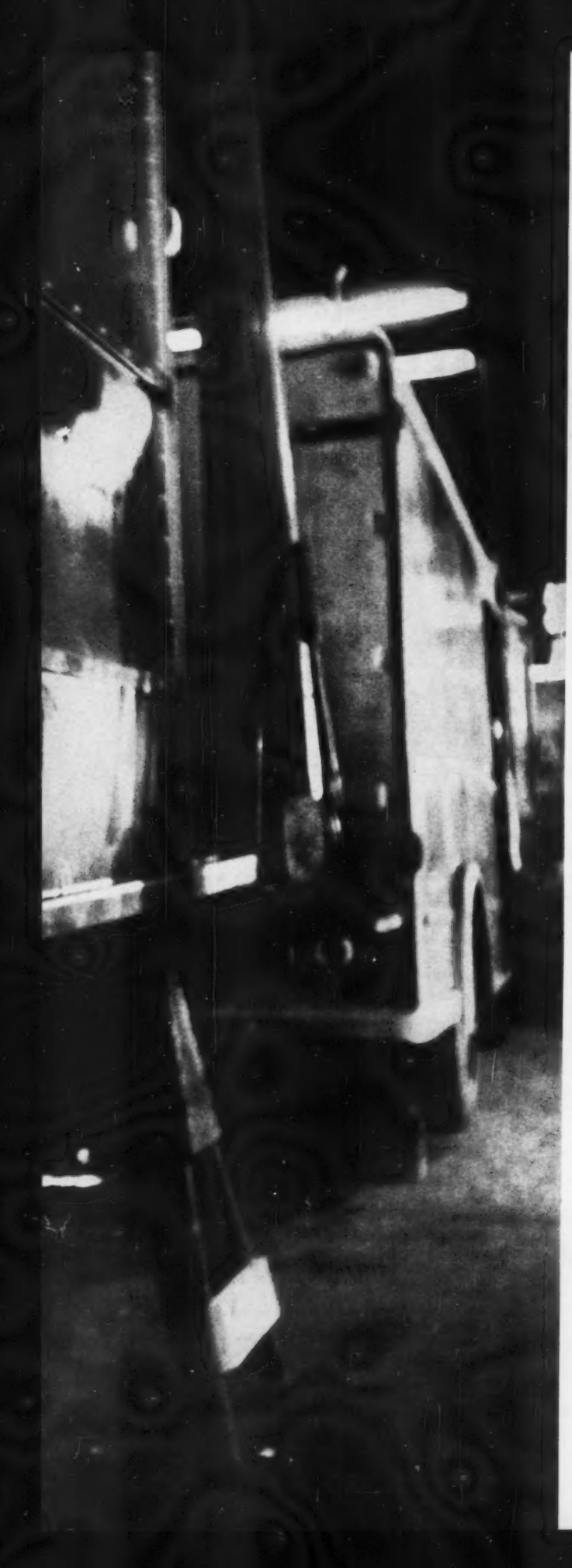
Available in 100 systematically spaced temperature ratings from 100° to 2500° F, inclusive .....$2.00 each.

Most leading industrial supply houses carry Tempilstiks°. If yours is an exception, write to us for further information and the name of your nearest distributor.

Tempil° CORPORATION • 132 West 22nd St., New York 11, N.Y.

Visit us at Booth 928 • 1961 ASM Show • Cobo Hall, Detroit, Michigan • October 23-27

Circle 1470 on Page 48-P



HOW BOYERTOWN KEEPS EVERY BODY HAPPY

Boyertown Auto Body Works of Boyertown, Pennsylvania is keeping delivery truck owners, drivers and maintenance men especially happy these days by using a new, all-around material in its body construction: J&L Nickel-Copper-Titanium high-strength forming steel.

The owner is pleased because lighter weight means lower operating cost. And Boyertown has been able to save from 600 to 650 pounds over mild steel in a 12-foot forward control delivery body—with no sacrifice of strength!

The driver is satisfied because the increased ductility of J&L Nickel-Copper-Titanium makes it possible for Boyertown to design bodies with greater flexibility—provide more convenience and safety for the man behind the wheel.

The maintenance man is happiest of all, though. J&L Nickel-Copper-Titanium has 4 to 6 times the corrosion resistance of mild steel. (For extra protection, Boyertown coats it with rust-inhibiting zinc chromate). It has greater abrasive and impact resistance, and less tendency to dent and wear.

When maintenance is necessary, dents can be easily "bumped out," and repairs are quick and inexpensive.

That's why Boyertown—a pioneer in the use of high-strength steel—continues to specify J&L Nickel-Copper-Titanium for its exterior and interior truck panels, posts, ribs, cross members, floors, doors and windshield assembly. Ask your J&L salesman about J&L's other new high-strength steels, JLX-W Columbium-Bearing and J&L "Cor-Ten."

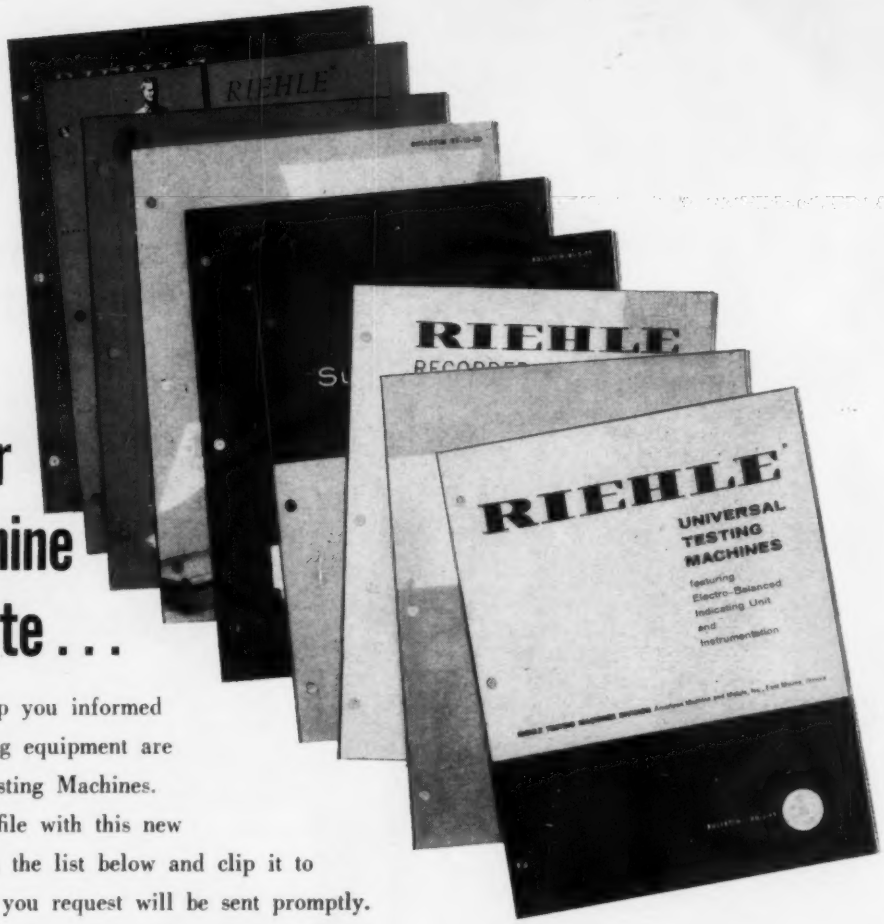
Jones & Laughlin Steel Corporation
3 Gateway Center, Pittsburgh 30, Pennsylvania

J&L STEEL

Circle 1466 on Page 48-B

EASY WAY

to bring your testing machine file up to date...



New bulletins* to help keep you informed about today's modern testing equipment are being offered by Riehle Testing Machines. To up-date your reference file with this new technical information, check the list below and clip it to your letterhead. Literature you request will be sent promptly.

CHECK BULLETINS WANTED — MAIL TODAY

- ☐ *Riehle Recorder and Accessories plus Supplement
- ☐ *Riehle Universal Testing Machines Featuring Electro-Balanced Indicating Unit and Instrumentation
- ☐ Creep and Stress-Rupture Testing Machines
- ☐ An Axial Loading Creep Machine
- ☐ *The Riehle-Los Hydraulically Actuated Fatigue Testing Machine
- ☐ *Measuring Instrumentation Components and Complete Systems for Force and Distance
- ☐ Construction Materials Testing Machines and Accessories
- ☐ Torsion Testing Machines
- ☐ Glossary of Terms Representing Mechanical Properties and Tests
- ☐ Brinell Hardness Testers
- ☐ Vickers Hardness Testers
- ☐ Portable Hardness Testers for Rockwell Readings
- ☐ Hardness Conversion Chart for Hardened Steels
- ☐ Impact Testing Machines
- ☐ The Charpy Impact Machine and Procedure for Inspecting and Testing Charpy V-Notch Impact Specimens
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- ☐ Handsome wall plaque, reading: "One Test is Worth a Thousand Expert Opinions."™

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HUNTER SPRING COMPANY • GLASER-STEERS CORPORATION

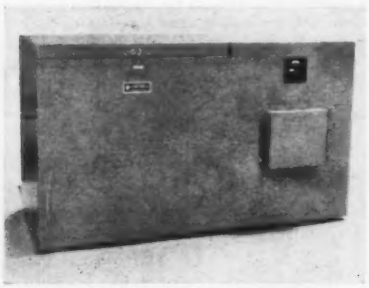
Circle 1467 on Page 48-B

NEW PRODUCTS

Heating

Cabinet for Metallurgical Chilling

The use of liquid CO_2 for the initial temperature reduction of stainless steel prior to rerolling is costly. *Cincinnati Subzero Products,* by modifying heavy-duty chilling units used in stabilization and precipitation hardening, is supplying chambers which will chill stainless steel to −150° F. The

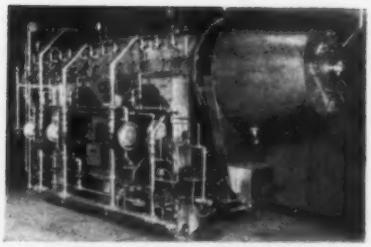


"Model ST-120-15", on display at the Detroit Metal Show, will chill 200 lb. of steel per hr. from ambient to −120° F. The 36 by 24 by 30 in. chamber has a capacity of 4000 Btu. per hr. at −120° F. and requires 440-v., 60-cyle, three-phase power plus a 115-v. control circuit.

For further information circle No. 1195 on literature request card, p. 48-B

Automatic Carburizing Furnace

The *American Gas Furnace Co.* will exhibit at the Detroit Metal Show an improved and larger "Automotion" furnace with a capacity of 800 lb. per hr. Advantages of the "Model 139-MDR" in continuous heat processing and case hardening are lower operating and maintenance costs plus processing uniformity, since parts are kept

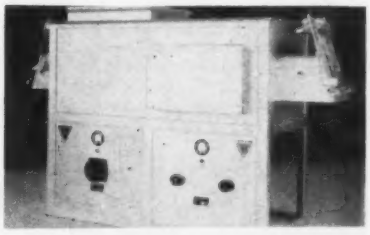


in motion during heating, exposure to atmosphere, and quenching. Available in standard sizes with capacities up to 1500 lb. per hr., the 600° to 1850° F. operating range of the furnace permits processing of ferrous and nonferrous parts.

For further information circle No. 1196 on literature request card, p. 48-B

High-Temperature Electric Furnace

The "Model SNXKSG" furnace has two adjacent hot zones, one operating at 2900° F. and the other operating simultaneously at 2300° F. Each zone has a work area 6½ in. wide by 24 in. long by 2½ in. high and is equipped with its own temperature recorder, saturable core reactor, and tap-transformer to assure maximum flexibility and control. The furnace is available in any combination of preheat, high-temperature and cooling zones, and is furnished with all necessary power controls plus platinum thermocouples. *Pereny Equipment Co.*



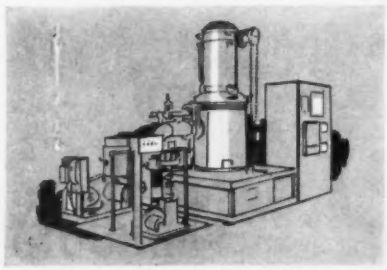
For further information circle No. 1197

Vacuum Heat Treating Symposium - Cobo Hall Rm. 3035, 2 to 5 PM, Mon., Oct. 23
See us in Booth 938 at the Metal Show

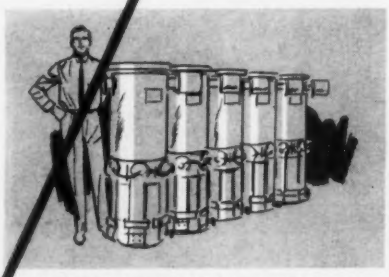
THESE HAYES VACUUM FURNACES WERE DESIGNED FOR INDUSTRIAL HEATING JOBS TOO HOT TO HANDLE BY OTHER FURNACES!

C. I. Hayes is *the pioneer* of vacuum heat treating furnaces. But more important, Hayes still leads today in the development of new, high-temperature, high-vacuum furnaces to meet the needs of Industry. Here are just a few examples of how Hayes solved tough and unusual heat treating problems with Vacu-Master furnaces . . . in each case coordinating furnace design with job requirements.

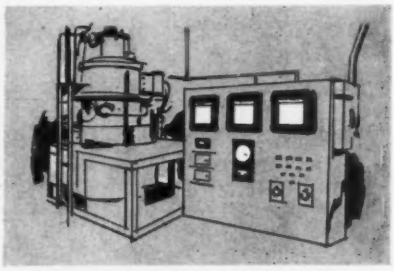
The *versatility* of Hayes Vacu-Master Furnaces has been proved . . . from sintering at temperatures to 4600°F to a wide variety of conventional applications including annealing, brazing, hardening, tempering, sintering and degassing. Perhaps *your* heat treating problem can be solved more efficiently, more economically with a Hayes Vacu-Master furnace.



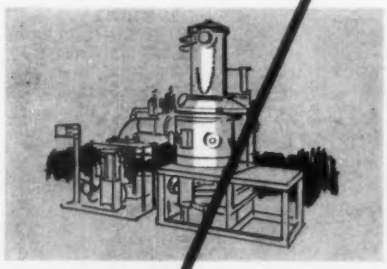
* **In Upper New York State,** this Hayes Vacu-Master operates in the 2200-2300°F Temperature range at sub-micron vacuum for brazing complex stainless steel assemblies. The Hayes cold-wall, fully water-jacketed furnace design provides most efficient cooling of the vacuum chamber . . . and contributes to operating comfort. On one job alone, the Vacu-Master has reduced reject rate four fold.



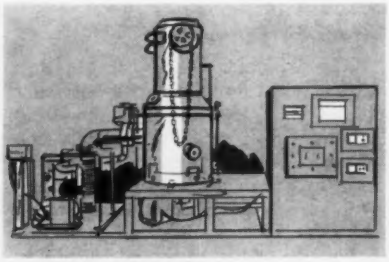
* **The Atomic Energy Division of a Delaware Corporation** utilizes the close temperature control (less than ± 10°F) of this high-speed Hayes Vacu-Master in the 2000°F range for a specialized processing job. Heating chamber of the Vacu-Master has no metal retort. Direct heating means extremely rapid cycling . . . higher quality processing at tremendous savings.



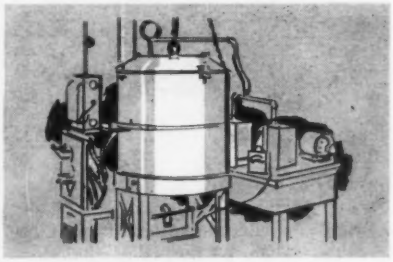
* **Installed In A West Coast Aircraft Plant,** this Hayes Vacu-Master provides automatic programmed control for a complex brazing operation. Temperature control of workpiece is within ±5°F. Vacuum processing plus high speed vacuum cooling insure correct metallurgical structure. Hayes Vacuum Furnaces feature saturable reactor controls to keep element and workload temperatures uniform . . . keep furnace downtime and maintenance to the minimum.



* **At Another New York Plant,** a beryllium-copper hardening job called for a furnace that could operate in the 650°F range within ±3°F — also a furnace capable of handling by simple changes in control settings Ni-Span C (1400°F range), stainless steel annealing, copper brazing, etc. The answer: this versatile Hayes Vacu-Master with wide-range temperature capabilities. The result: quality output without costly rejects.



* **Mid-West Auto Parts Manufacturer** proved the versatility of this Hayes Vacu-Master to handle general heat treating applications in 600°F to 2200°F temperature ranges. With it, the company has been able to perform economically many difficult annealing, hardening, and brazing operations.



* **FIRST Commercial Vacuum Furnaces** sold to industry were designed by Hayes in 1929 for one of the nation's largest electrical manufacturing firms. These production-scale vacuum furnaces were used for processing vacuum tube components. Advanced design features included full-jacket cold wall construction . . . way ahead of contemporary equipment! They're still working today!

Complete lab facilities are at your disposal *without cost*. And results are *guaranteed*! Write for Bulletins 5709A and 5709B describing Hayes Vacu-Master furnaces.

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*NAMES OF COMPANIES ON REQUEST.

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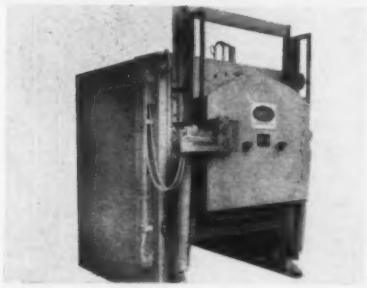
Established 1905

802 WELLINGTON AVE. • CRANSTON 10, R. I.

Combined with "Stump the Experts" panel
COBO HALL RM 3035 • 2 to 5 PM • Mon., Oct. 23

Circle 1468 on Page 48-B

Electrically Heated Box Furnace

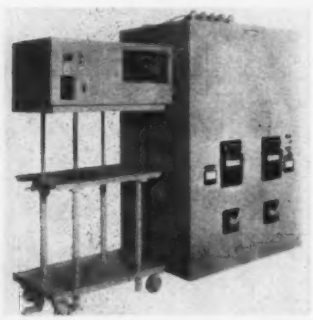


Employed in hardening, annealing, normalizing, and preheating, this unit may be operated with or without a protective atmosphere up to 1950° F. Heating elements are located in the door, sidewalls, and below the hearth for even heat distribution. The furnace is built in 21 sizes with heating chambers ranging from 8 in. wide by 18 in. long by 5 in. high to 48 by 96 by 30 in high. *Sunbeam Equipment Corp.*

For further information circle No. 1198

Four-Tube Diffusion Furnace

The 36-in. long heating chambers in this unit will reach a maximum temperature of 1300° C. (uniformity, ±1° C. in 18 in.). Each of the two zones has 12 "Globar" elements, a 9 kva. tap-transformer and a proportioning unit to indicate control temperatures. A detachable, automatic pusher mechanism has adjustable travel stops, a soak timer (up to 30 hr.) and a variable-speed control; it accommodates four pusher arms having a travel distance of 34 in. *Lindberg Engineering Co.*



For further information circle No. 1199 on literature request card, p. 48-B

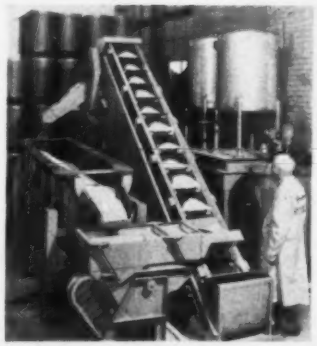
Amplifier for Proportional Power

A magnetic amplifier system made by *Hevi-Duty Electric Co.* can control temperature in an electric furnace within 0.1° at 1400° C. Coupled with a saturable core reactor the unit is the electrical equivalent of an equal percentage valve in that a linear change in the system input will produce a percentage change in process power. Believed to be the first truly proportional power system, it can also be used to control any mechanical or electrical process where a proportional power curve is required. The instrument operates from any automatic control system on 110-v., 60-cycle, single-phase power with a 0 to 5 milli-amp input; output is 0 to 85 v., d-c.

For further information circle No. 1200

Finishing

Continuous Automatic Finishing

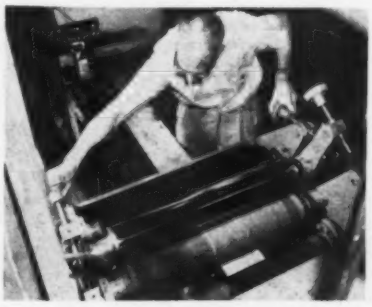


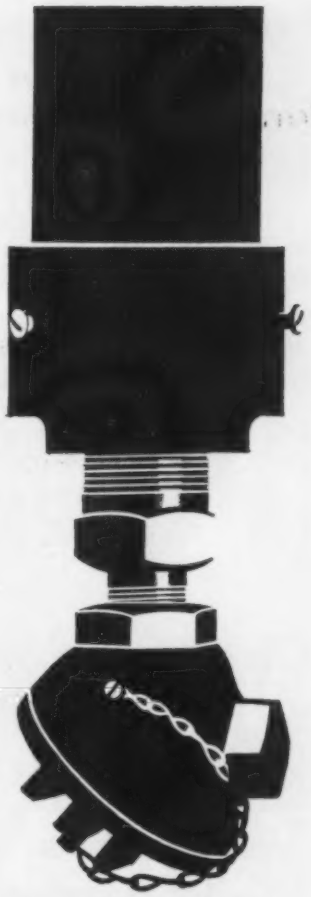
High-production finishing of metal, plastic, or ceramic parts is possible with a new line of vibrating gyrators from *Pangborn Corp.* Operating without supervision, the unit automatically conveys the work; cleans, screens, and recirculates media; and adds water and compound as required. Using the same gyrator action and air-cushion suspension as standard units, the machine cleans, descales, deburrs, grinds, colors, and burnishes with equal precision and uniformity.

For further information circle No. 1201 on literature request card, p. 48-B

Roll Coating of Alodine

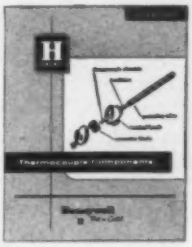
Alodine, the amorphous chromate prepaint finish, can now be applied to





THERMOCOUPLE COMPONENTS

Wires, insulators, protecting tubes, heads, blocks, connectors and miscellaneous components—supplied in countless combinations, for highest possible accuracy in any given application. Thermocouple components are among many thousands of accessories—all available from a single dependable source—that can help your instruments perform at their very best.



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Honeywell

First in Control

SINCE 1885

Circle 1469 on Page 48-B

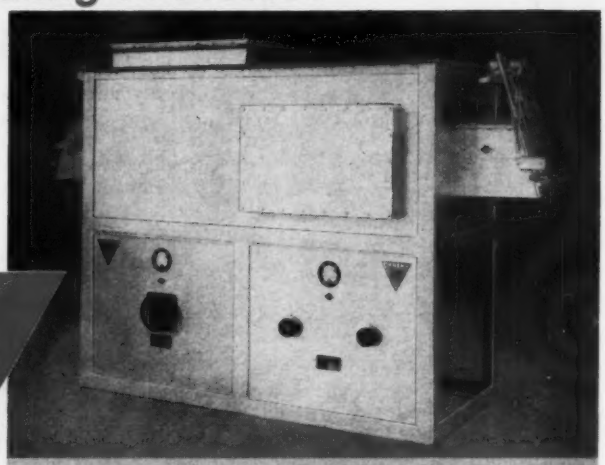
For those Critical Heat Treating Processes

calling for high temperature with precise* and flexible control—

PERENY EQUIPMENT COLUMBUS O

PERECO Straight-Line FURNACES

SNX SERIES

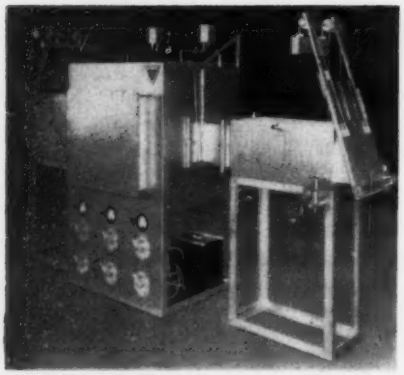


for controlled atmosphere at temperatures from 1300°F to 2900°F

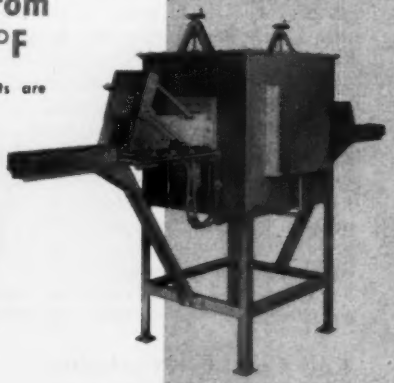
*For the ultimate in precision control, Pereco units are available with saturable core reactor systems.

For sintering, brazing, reduction, annealing, metallizing and coating, calcining and experimental work in many other areas.

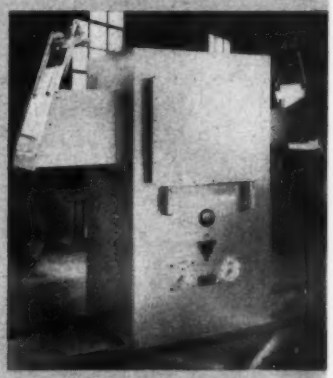
Pereco Series SNX Straight-Line Furnaces are available in any multiple or combination of pre-heat, high temperature, and cooling zones depending upon the requirements of the work to be handled. For example, the unit shown above has *two* immediately adjacent hot zones; one operating at 2900°F while the other operates simultaneously at 2300°F. The high temperature zone is heated with molydisilicide elements and the other with silicon carbide elements. Each has its own power controls. This arrangement, as well as other special operating features — coupled with Pereco proven design "know-how" and high-quality furnace construction — typifies Pereco's capabilities for designing or modifying a straight-line furnace to meet specific needs.



An SNX unit which has a 3-stage "hot" zone separated from both the pre-heat and water-cooled exit zones by interior blast gates, manually operated from outside.



Above: Model SNX-200, for controlled atmosphere work in sintering powdered metals, brazing and other specialized applications in metallurgy or ceramics. Automatic, solenoid-operated flame curtains, with manual or mechanical pusher system optional.



Above: A 3-zone, straight-line, manual pusher-type furnace (SNX-81072) suited to a wide variety of high temperature (maximum 2700° F.) heat treating work. Hot zone incorporates 2 separately controlled banks of silicon carbide heating elements.

Write Today
for Pereco Recommendations and "get-acquainted" bulletin

PERENY EQUIPMENT CO., INC.

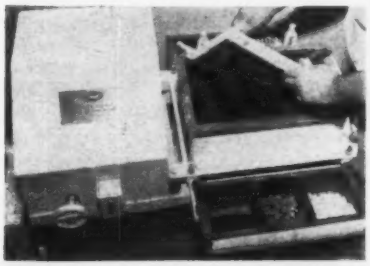
Dept. Q, 893 Chambers Road — Columbus 12, Ohio

Circle 1465 on Page 48-B

coils of aluminum by roller coating. The equipment handles coils up to 24 in. wide at speeds up to 150 ft. per min. Reducing application time from 15 sec. to 5 sec., the alodine solution is never reused – eliminating the need for chemical control and costly equipment to remove harmful contaminants. The corrosion-resistant aluminum coils produced are fabricated into awnings, siding, and other building products. *Amchem Products Inc.*

For further information circle No. 1202 on literature request card, p. 48-B

Seven Finishing Jobs — Simultaneously



Five side tubs and a divider for the main tub allow finishing of many different parts at the same time in a "Vibrahone" machine. The auxiliary units, which save time, labor, and capital investment in finishing small runs of different sized parts, are rubber lined to cushion workpieces. The tubs tilt for rapid draining and are easily attached to any size of finishing machine. *Minnesota Mining & Mfg. Co.*

For further information circle No. 1203 on literature request card, p. 48-B

Nylon-Clad Baskets

Special wire baskets made by *Wiretex Mfg. Co.* eliminate damage to polished precision parts during handling and ultrasonic cleaning. Representing a cost saving of 40% over stainless steel baskets, the nylon-coated fixtures prevent metal-to-metal contact and stand up well under rigorous ultrasonic cleaning action. The nylon coating has high moisture resistance (less than 0.5% pickup), is unaffected by most solvents, and has the highest temperature resistance of any thermoplastic material.

For further information circle No. 1204 on literature request card, p. 48-B

Buffing Compound Cleaner

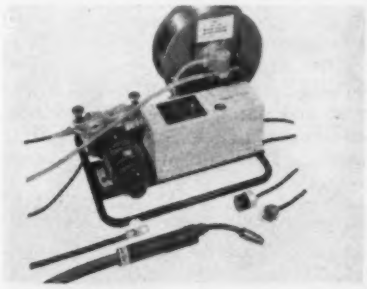
Cowles Chemical Co. announces a compound for cleaning bar and liquid-type buffing compounds from zinc die castings. Proven effective in numerous production tests, "Buff-Off" contains no amines, which often interfere with plating operation. The product will not streak, etch, or darken castings. Because it is stabilized, control procedures are simplified; only product additions are necessary to maintain efficient operation.

For further information circle No. 1205 on literature request card, p. 48-B

Welding

Welding Light-Gage Metal

Semiautomatic "MiniArc" equipment welds light-gage metals in any position, is fast in operation, and eliminates much clean-up time because it reduces spatter. Consisting of an AM-8 torch, WC-5 control with wire



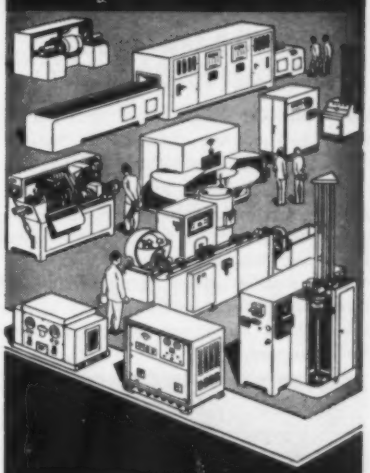
drive, and interconnecting gas and flexible conduit assemblies, the unit has a wire feed rate from 55 to 500 ipm, and can handle wire diameters of 0.025, 0.030 and 0.035 in. In addition to CO_2 and argon-CO_2 mixtures for shielding, the MiniArc can use pure argon and pure helium. *National Cylinder Gas Div.*

For further information circle No. 1206 on literature request card, p. 48-B

All-Position Welding Electrode

Air Reduction Sales Co. offers an E7018 iron powder, low-hydrogen electrode for all-position welding of steel. The balanced coating on the "Easyarc 328" (conforms to MIL-22200) provides fast, efficient metal transfer in welding low-alloy, high-strength steel and mild steel as well

for HARDENING • BRAZING
SOLDERING • FORGING • ANNEALING
MELTING • SINTERING • WELDING
REFINING • SHRINK FITTING
CRYSTAL GROWING



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Manufactures the most complete range of

INDUCTION HEATING EQUIPMENT

ELECTRONIC • LOW FREQUENCY
MOTOR GENERATOR

THER-MONIC features

• Over 20 years of concentrated experience.

• Over 5,000 installations.

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• This outstanding experience and know-how qualify us to prescribe the techniques and equipment best suited for your requirement.

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INDUCTION HEATING CORP.
181 WYTHE AVE., BROOKLYN 11, N.Y.

Subsidiary of Hathaway Instruments, Inc.
Circle 1471 on Page 48-B

YOUR TESTING EQUIPMENT:

Does it measure up to space age requirements?

Look to INSTRON for advanced instrumentation to meet the challenge of testing requirements in modern metallurgy.

Today's Instrons are assisting researchers in the development of a broad range of space age materials ranging from high-temperature alloys to high energy fuels — solving some of today's most difficult problems, many of which are beyond the range of conventional test equipment.

THE INSTRON UNIVERSAL TESTER — Performs tension, compression, flexure, creep, hysteresis, and other tests of mechanical behavior. For high precision studies of all types of metals and alloys, including such special materials as whiskers, single crystals, and pyrolytic graphite. Handles wide load ranges through low inertia weighing system. Servo controlled testing speeds from 0.002 to 20 inches per minute. Various models and sizes to meet widest range of applications. Full scale load ranges: 2 grams to 10,000 lbs.

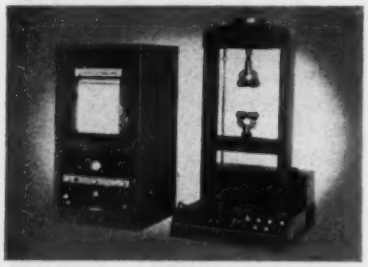


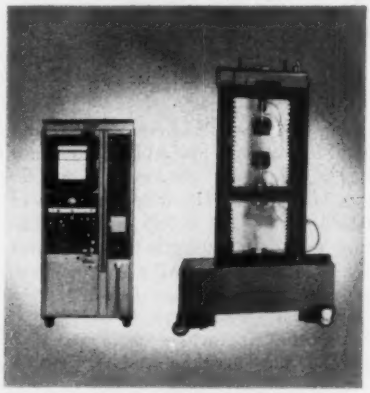
TABLE MODEL INSTRON — Compact design with complete line of accessories for automatic load and extension cycling, stress relaxation and energy measurements. Economical, versatile instrument for testing foil, fine wire, and other light samples. Full scale load ranges: 2 grams to 200 lbs.

HIGH-TEMPERATURE TENSILE TESTING EQUIPMENT — To meet the demands of modern metallurgical engineering, Instron offers equipment for performing tensile tests at temperatures up to 2200°F, in either a vacuum or controlled atmosphere.

The result of extensive development work, and established in years of actual application, this unique equipment has proven valuable in high temperature alloy research, particularly in studying the behavior of such metals as molybdenum, titanium, and niobium.

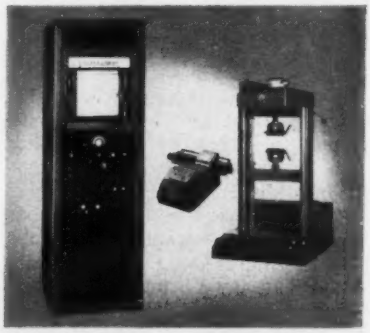
Available in single or dual furnace models.

INSTRON HIGH TEMPERATURE CREEP TESTING EQUIPMENT — Makes possible highly accurate creep measurements at temperatures up to 2200°F in air or controlled atmosphere. Unit includes vacuum-tight capsule with pull rods, grips and gaging apparatus, precision self-compensating lever loading system, furnace, and separate recorder-controller.



EQUIPMENT FOR RADIOACTIVE TESTING — Remote control equipment for in-cell testing of irradiated materials. Design permits testing assembly to be moved in and out of the hot cell with ease — features such advantages as 50:1 selection of full scale load ranges with a given load cell; 1000:1 remote selection of crosshead speeds; remote, servo-operated dials; and remote air-operated grips.

INSTRON CAPILLARY RHEOMETER — For measuring flow properties of polymers and other non-Newtonian fluids. Consists of extrusion assembly mounted on conventional Instron Universal Tester, with temperature controls contained separately. Sample is forced out through a capillary by a plunger driven by the moving crosshead. Features: constant shear rates; wide range of speeds; permanent data recording; interchangeable capillaries; high precision heat control (to ±0.5°C.)



DIGITAL PRINTOUT SYSTEM — Complete system incorporated in either floor model or table model INSTRON. Provides automatic printout of selected values from stress-strain curves. System ideally suited for high volume testing in quality control and statistical applications. Selected parameters for printout may include maximum load or stress; breaking load or stress; extension; energy to break, modulus, etc.

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For advanced instrumentation in stress-strain behavior, look to

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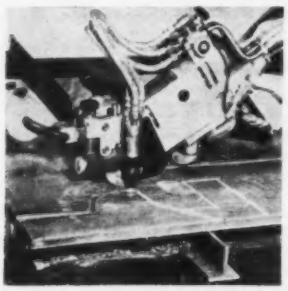
Circle 1472 on Page 48-B

as high-carbon, high-sulfur, and enameling steels. Used with alternating or direct current, reverse polarity, the electrode is available in 14 in. lengths and in 3/32, 1/8, 5/32 and 3/16 in. diameters.
For further information circle No. 1207

Portable Flame-Cutting Machine

Fast, clean cuts in metal ranging in thickness from light-gage sheet to 2-in. plate can be made with *Linde Co's* CM-75 "Cadet". This 19-lb. machine is equipped with a clutch for instant free-wheeling control. Operating at



speeds up to 30 ipm., it can be used with acetylene, propane or natural gas for straight-line, bevel, circle, and contour cutting. The unit comes complete with torch, rigging, four nozzles, circle-cutting attachment, a set of balance weights and a heat shield.
For further information circle No. 1208 on literature request card, p. 48-B

D-C. Arc Welder

Simplified controls for gas-shielded and submerged arc welding are featured on the *Westinghouse* "Model RCP". This 500 to 600 amp. selenium rectifier unit, suitable for semi-

automatic and automatic operation, provides relatively flat volt-ampere characteristics for maximum arc stability. This insures instant arc starting and recovery, as well as reduced burn-back and stubbing. Other features of the machine include open-circuit voltage control and "de-ion life-linestarter" welder control.
For further information circle No. 1209

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FABRICATED HEAT AND CORROSION RESISTANT ALLOYS

STANDARD
BASKETS
AND GRIDS

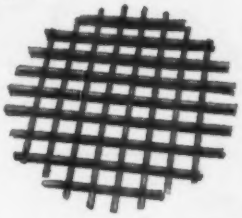
with a basketful of specific money-saving features

Standard for use in Hevi-Duty furnaces.

Four-trunnion top ring.

Standard for use in L & N furnaces.

- FABRICATED — not cast . . . for more consistent performance in the furnace and in the quench.
- LESS BASKET WEIGHT — more payload.
- TREMENDOUSLY RUGGED . . . top rings, bottom rings, sidewalls.
- FASTER RECOVERY TIME . . . more efficient, economical furnace operation.
- ENGINEERED to withstand THERMAL SHOCK better than heavier designs.
- EASIER TO HANDLE.
- ROLOCK PRESSURE WELDED GRIDS . . . with round rods and LOW-MASS joints, do not crack, last much longer.



Customer "X" (name on request) is just one who reported such practical savings as "one extra eight-hour cycle per week."

And finally please note that our STOCK program on popular sizes and types of baskets, trays and grids enables us to assure PROMPT shipment. Let us quote on your current needs.

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ROLOCK, INC., 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

3RL61

Circle 1473 on Page 48-B

KENNAMETAL*

HARD CARBIDE ALLOYS AND METALLURGICAL PRODUCTS

PRODUCTS	PROPERTIES	TYPICAL APPLICATIONS
Kennametal (tungsten-base carbides)	YME of 60 to 90 million psi. Compressive strength higher than virtually all melted and cast or forged metals and alloys. Kennametal outwears steel up to 100 to 1. Impact strength in the range of hardened alloy steels of very much lower hardness and compressive strength. Thermal expansion about half that of steel. Compositions to withstand one or various combinations of destructive agents such as abrasion, corrosion, galling, impact, and erosion, or meet specific requirements as to stiffness, strength and weight.	Metalworking and mining tool cutting edges. Die inserts. Seal rings. Integrator discs. Needle valves and cones. Compressor liners. Pulverizing hammers. Abrasion resistant knives, blades, shears. Boring bars. Spray orifices. Balls and seats for oil well pump valves.
Kentanium* (titanium-base carbides)	Superior strength and abrasion resistance at temperatures 1800°F. and up . . . temperatures that rapidly destroy conventional carbides or high temperature cast alloys. Can be subjected continuously to operating temperatures up to 2200°F., and up to 5000°F. for short periods. Greater resistance to thermal shock than ceramics. Highest stiffness-to-weight ratio of any material . . . approximately ⅔ the weight of steel. YME up to 60 million psi.	Sensing elements for high temperature thermostatic controls. Spinning tools for hot metals. Flash-trimming tools. Turbine components. Balls for pump check valves. Nuclear reactor equipment. Rotary seal rings. Hot rod mill guide inserts. Anvils for spot welding. Balls for hot hardness testing.
Refractory Carbides	High purity. High melting point—5000°F. to 7000°F.	In powder form as basic materials. Acid resistant parts and crucibles. High temperature furnace parts.
Kennertium* (heavy tungsten alloys)	Nominal Density: 16.5 to 18.7 gm/cc. Machinability? Good. Tensile Strength: 40,000 to 90,000 psi. Corrosion Resistance: Excellent. Readily brazed with Easy-Flo No. 3 Compound. Available as bars, rods, rings, discs, special shapes.	Counterweights. Radioactive shielding. Isotope containers. Atomic watch shielding. Shielding—cobalt and X-ray medical equipment. Rotational parts—flywheels, governors, gyroscope components. Electrical contactors for high current, heavy duty applications.
Niobium	Metal—99.8% grade. Granules, arc melting electrodes, bar, strip. Metal—99.5% and technical grades. Powders, granules, arc melting electrodes. Oxide—99% and 99.5% grades. Fine powder.	Arc melting electrodes: Nominal size 1″ x 2″ x 20″. Niobium-base alloy electrodes also available. Powders: 20 to 80 mesh. Granules: 1/16″ to 40 mesh.
Tantalum	Metal—99.9% (capacitor) grade. Solid form—strip, bar, wire. Metal—99.5% grade. Granules. Metal Powder—99.8% grade. Fine powder. Oxide—99% grade. Fine powder.	Anodes: Sintered for both liquid and solid electrolytic capacitors, wide range of sizes. Strip: .001″ to .100″ thick, up to 12″ wide. Wire: From .005″ to .030″. Powder: 200 mesh. Other sizes available. Oxides: In analyses and particle sizes to meet specific requirements.

*Trademark

FOR DETAILED INFORMATION send for:

1. **Properties of Kennametal**—24-page outline of the company, its history, manufacturing methods and facilities. Plus a detailed description of Kennametal and Kentanium characteristics . . . physical and mechanical properties, with suggestions for design application.
2. **Kentanium**—12-page description of physical characteristics and applications.
3. **Designing with Kennametal**—42 pages of design ideas . . . problems and solutions in designing with carbides, fastening methods, typical applications.
4. **Proven Uses of Kennametal and Kentanium**—28-page case history book illustrating wear, component parts, and other special applications in 26 major industries. Cites customers' savings, Kennametal facilities, and services.
5. **Kennertium**—8 pages describing this new heavy tungsten alloy: properties, applications, machining and joining recommendations, and engineering service.

Write Dept. MDE, KENNAMETAL INC., Latrobe, Pennsylvania. 39012

INDUSTRY AND KENNAMETAL ...Partners in Progress

Circle 1474 on Page 48-B

Testing

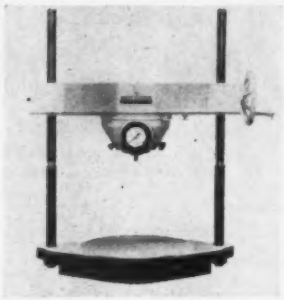
New Metallographic Apparatus

William J. Hacker & Co. will demonstrate new metallographic techniques and instruments at the 1961 National Metal Exposition in Detroit. Included will be "DP" polishing, electrolytic lapping, and metal microtomy using an automatic microtome. For high-temperature microscopy, a vacuum-heating stage with a range up to 1800° C. provides for rapid heating and cooling of samples while under microscope observation. An electronically controlled dilatometer and a thermo-balance represent new contributions to thermal analysis.

For further information circle No. 1210 on literature request card, p. 48-B

Air-Operated Hardness Tester

Brinell hardness of castings and other large parts can be easily determined with a wide-clearance (34-in.)



"Air-O-Brinell" tester from *Tinius Olsen*. Positive application of test loads to 3000 kg. is assured because load is indicated on test gage before being applied to the part. Once set, any number of tests can be conducted with full assurance of uniform load application. Operation requires only a small air supply – 1.2 cu.ft. of delivered air per min. – to maintain accuracy.

For further information circle No. 1211 on literature request card, p. 48-B

Electron Microscope

A series of attachments on the "Model JEM-6A" can heat, chill or subject a specimen to stress, as well as take motion pictures of metallurgical changes. The instrument has continuous direct magnification of 600 × to 200,000 ×. Electronic magnification can be increased by enlarging photographs made in the microscope. Resolving power is high – 12 Angstrom units under ordinary conditions, 8 A. under ideal conditions. A daylight-loading 16-mm. cine-camera takes motion pictures at speeds of 1.5, 3, or 6 frames per sec.; film can also be exposed one frame at a time. *Fisher Scientific Co.*

For further information circle No. 1212

Portable Strain Indicator

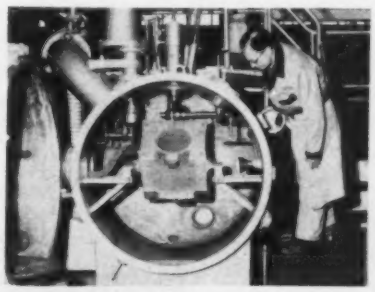
The "Type 20" indicator provides digital readout – eliminating interpolation from dials and meters – and doubled gage factor range (1.50 through 4.50). The instrument gives fast, dependable results with most strain gages in one, two, or four-arm networks, and with strain-gage transducers, bonded or unbonded. The counter gives readings from 0 through 5000 micro-in. per in.; accuracy is 0.1% of reading or 5.0 micro-in. per in., whichever is greater. The indicator also provides a demodulated output from the scope jack so that dynamic strains – up to 50 cycles per sec. and 5000 micro-in. per in. – can be seen, minus the carrier, on a cathode-ray oscilloscope. *Baldwin-Lima-Hamilton Corp.*

Circle No. 1213 on literature request card

Casting

Induction Melting Furnace

Designed for research and development work or short-run production, a vacuum furnace with a capacity of 50 lb. will be exhibited by *F. J. Stokes Corp.* at the 1961 Metal Show. The "Model 436-504" features a large-capacity alloy additions system, consisting of four 36-cu.in. buckets and one 200-cu.in. bucket enclosed in a feed chamber. The buckets empty onto a vibrating trough and chute in any sequence desired. Cycle time has been reduced by increasing pump-



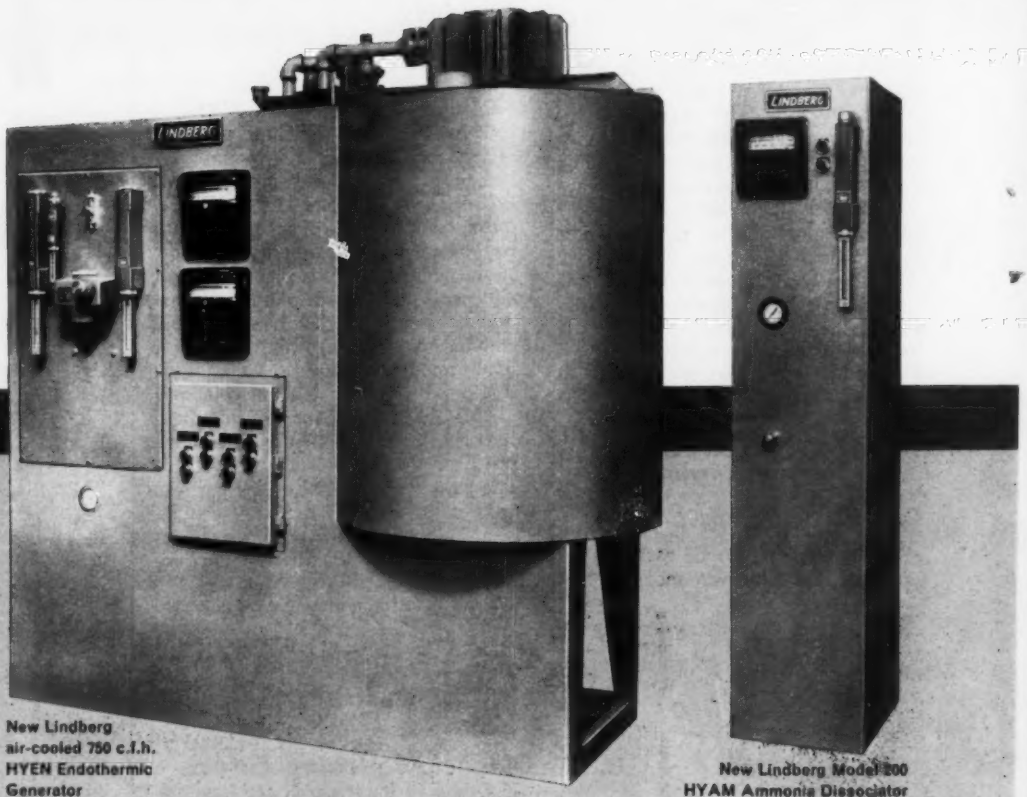
down speed of the vacuum pumping system, utilizing a "Model 1710" mechanical booster pump to back up a 10-in. "Ring-Jet" oil diffusion pump.

For further information circle No. 1214

AEROBRAZE
Now has FIVE Vacuum Brazing and Heat Treating Furnaces added to its hydrogen facilities to better serve the Metals Industry.
WHEN THE VACUUM TECHNIQUE is the preferred method for processing your finished parts, this added facility at Aerobraze can help you produce better products . . . at reduced cost.
BRAZING
HEAT TREATING
ANNEALING
HARDENING
DE-GASSING
SINTERING
OF
SUPER ALLOYS
REACTIVE METALS
COMMON METALS
Learn more about this ally for your alloys by visiting our Booth #908 at the 43rd NATIONAL METAL SHOW in Detroit, Oct. 23-27.
AEROBRAZE
CORPORATION
30012 Lakeland Blvd., Wickliffe, Ohio
Phone: WHitney 3-6330
Circle 1475 on Page 48-B

There's one sure way

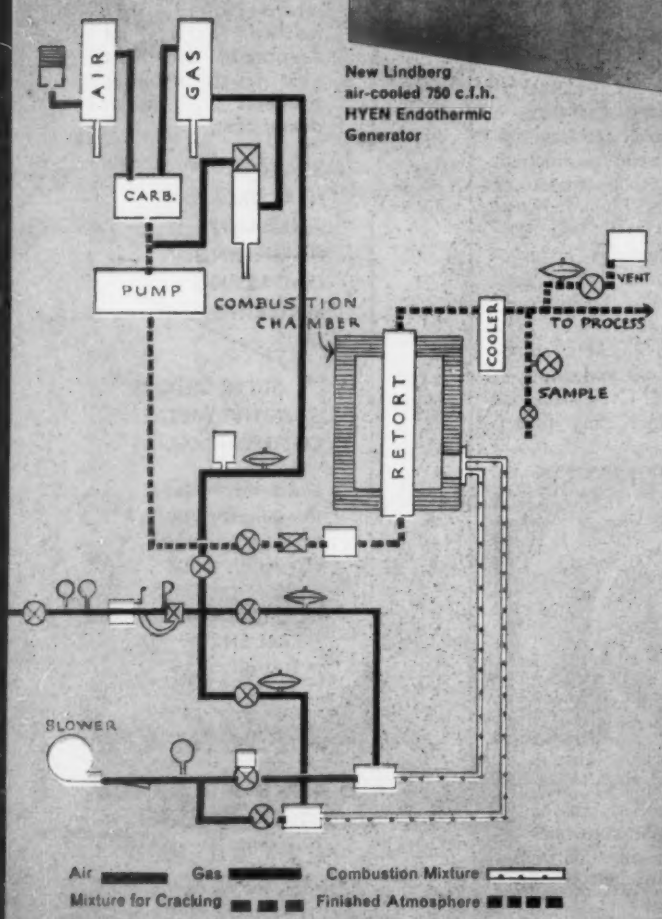
You'll see these brand-new Lindberg Generators at the Metal Show



New Lindberg air-cooled 750 c.f.h. HYEN Endothermic Generator

New Lindberg Model 200 HYAM Ammonia Dissociator

Schematic Flow Diagram of Lindberg HYEN Generator



To be shown for the first time are two Lindberg generators designed and engineered for improved efficiency and economy in the production of metallurgical atmospheres.

The new Lindberg HYEN ENDOTHERMIC GENERATOR is a fully automatic process for producing low cost protective atmospheres for bright hardening, bright annealing or bright brazing of steel totally free from decarburization or carburization. It will provide significant production economies, more precise operation and lowered maintenance costs. This new unit is *air-cooled*, eliminating the expense and trouble of water cooling systems. The HYEN Generator is available in 200, 500, 750, 1000 and 1500 c.f.h. capacities and larger sizes can be provided if desired.

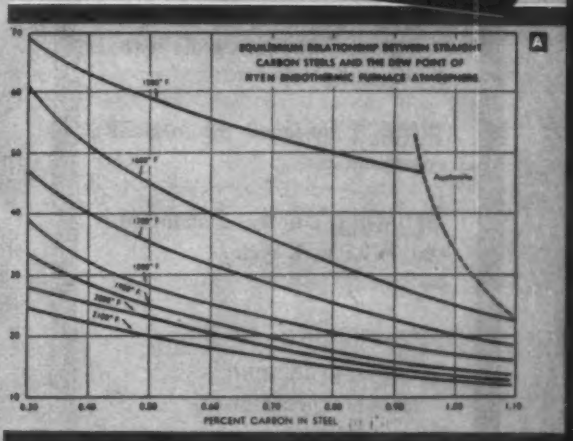
The Lindberg HYAM AMMONIA DISSOCIATOR, Model 200, is a brand-new development offering a combination of efficiency, capacity and compactness never before available to industry. The unit requires *less than 2 square feet of floor space.* Operating at capacities up to 200 c.f.h., it is *guaranteed* to maintain or exceed 99.95% dissociation efficiency (at 150 c.f.h. 99.99% efficiency is guaranteed). It is particularly designed for pilot plant applications, research and development, where high purity of atmosphere is required.

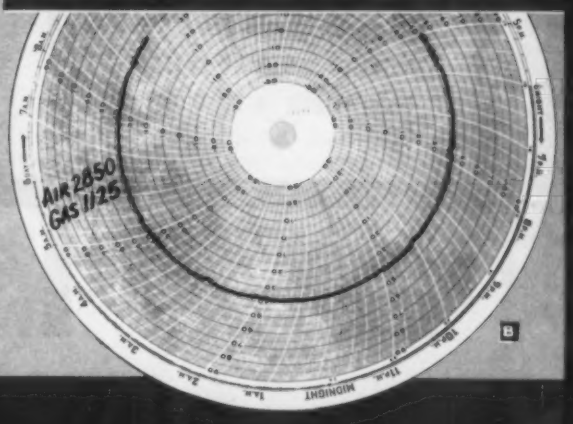
LINDBERG
heat for industry

to get the right information on methods and equipment for producing and controlling metallurgical atmospheres

Lindberg Carbotrol available for either dew-point or CO_2 infra-red control systems

A—Dew point equilibrium curves for use with Carbotrol have been established by Lindberg for types of steel and temperatures involved. B—Typical graph of Carbotrol performance. Note consistency of control.


A
EQUILIBRIUM RELATIONSHIP BETWEEN STRAIGHT CARBON STEELS AND THE DEW POINT OF NYKEN ENDOTHERMIC FURNACE ATMOSPHERE
Austenite
PERCENT CARBON IN STEEL



Talk it over with Lindberg in Booth No. 706 at the Metal Show

Because of the importance of metallurgical atmospheres in metal working we are giving the subject major emphasis in our exhibit at the Metal Show. Visit us there and you'll be able to learn about all the latest developments in methods and equipment for producing and controlling these atmospheres. You'll find us well qualified to offer authoritative advice in this field because we've pioneered in it.

In equipment, the first endothermic atmosphere generator was developed by Lindberg many years ago. Through the years generators for varied types of metal treating atmospheres have been developed, including units for exothermic, dissociated ammonia and inert atmospheres. And we have kept adding refinements and improvements to set continually higher standards of efficient and economical performance.

Years ago, too, Lindberg designed the first equipment for controlling metallurgical atmospheres, the Lindberg Carbotrol. For this, Lindberg research also created dew point equilibrium curves to establish proper atmosphere values for types of steel and temperatures involved. The Carbotrol automatically controls these values. It is also available incorporating the new CO_2 infra-red system of control. Since Lindberg makes both types we are in an ideal position to recommend the method most suitable for your specific processes.

When you visit us at the Show you'll also be able to get the latest information on Lindberg's complete line of heat treating equipment, everything from a laboratory furnace no bigger than a breadbox to a gantry type installation six stories high.

If you don't get to see us at the Show you can get full information on all Lindberg equipment from your local Lindberg Field Engineer (see your classified phone book) or write us direct. Gas Process Division, Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, Spain, Switzerland and West Germany.

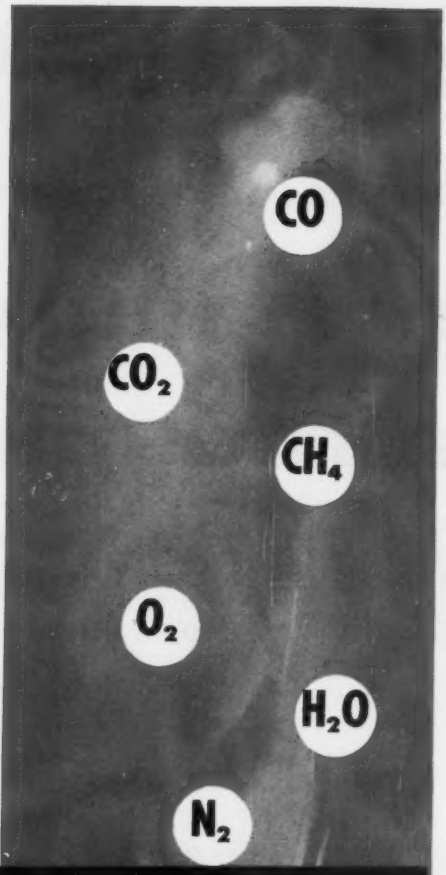
Circle 1476 on Page 48-S

FROM RCI

the
NEWEST
FURNACE GAS ANALYZER
built specifically to analyze gas components in furnace atmospheres

typical applications include:

HEAT TREAT FURNACES
BLAST FURNACES
ANNEALING LINES
OPEN HEARTH FURNACES
GAS GENERATORS



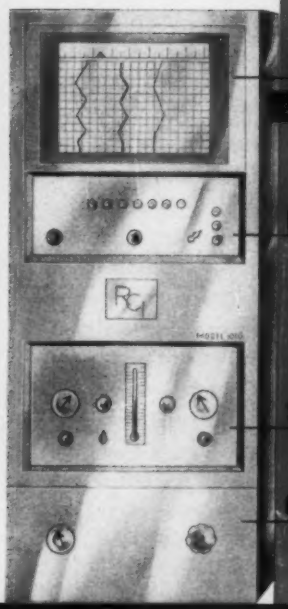
SIMPLE gas chromatography technique eliminates delicate optics and glassware.

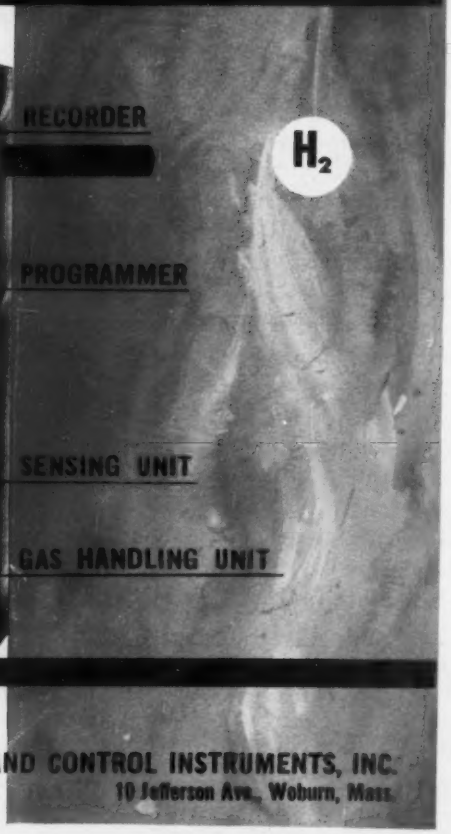
RUGGED designed for in-plant environment.

RELIABLE automatic standardization for each cycle.

FEATURING:

- TREND RECORDING — for up to eight components
- COMPLETE ANALYSIS every five minutes or less
- BUILT-IN SAMPLING SYSTEM
- COMPATIBLE WITH CONTROL SYSTEM

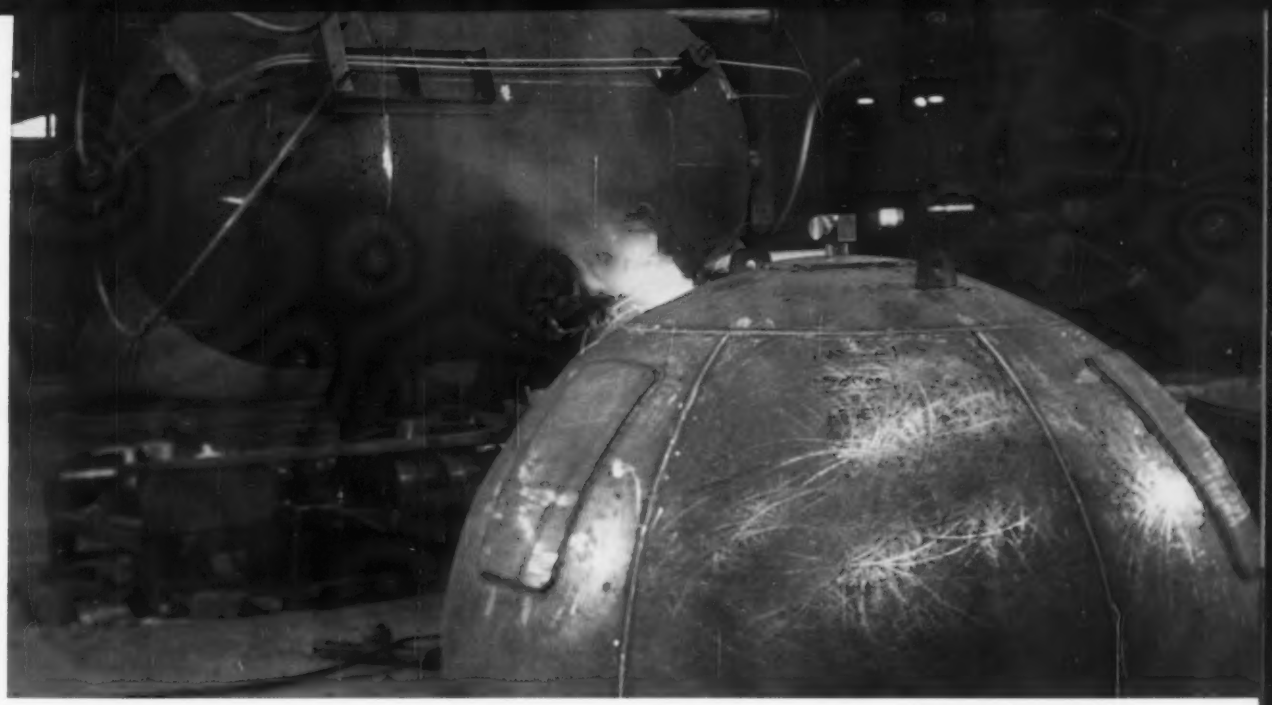




Visit us at the Detroit Metal Show — Booth 1133.
See the RCI Furnace Gas Analyzer and also get full information about RCI's Direct Reading Spectrometers.

RCI RESEARCH AND CONTROL INSTRUMENTS, INC.
10 Jefferson Ave., Woburn, Mass.

Circle 1477 on Page 48-B



USS 9% Nickel Steel reduces cost of handling cryogenic liquids

More than 400 vessels of 9% nickel steel have been put to use storing liquids at temperatures down to −320°F. The hemispherical heads shown being fabricated here are designed for liquid oxygen storage at −297°F. Some of these ASME Code designed and stamped vessels were fabricated of USS 9% Nickel Steel at Pittsburgh-Des Moines Steel Company for use by Air Reduction Company, Inc., New York.

The vessels are 9 feet in diameter and 16 feet in overall length including the heads. They will operate at a normal design pressure of 270 psi. Plate thicknesses are 0.700" in shell plates and 0.375" and 0.350" in head segments. Tanks were stress-relieved after welding.

Low carbon, 9% nickel alloy steel was developed to provide a ductile, moderately priced steel for storing such cryogenic liquids as ethylene, methane, oxygen and nitrogen in the range from −150°F to −320°F.

USS 9% Nickel Steel maintains good strength, toughness, and excellent ductility at sub-zero temperatures down to −320°F. At room temperature it has a minimum yield strength of 65,000 psi and high charpy impact values, while at −320°F, double-normalized and tempered 9% nickel steel shows a 36% increase in yield strength, and charpy keyhole impact values range from 20 to 40 ft/lbs. Since tensile properties and impact values are even better for quenched and tempered 9% nickel steel, recognition by various code groups of the suitability of such treatment is now being considered.

10% lower costs. Accumulated data on cryogenic vessels of 9% nickel steel suggest that minimum savings of 10% of the final erected costs can be expected from advantages in welding and fabrication alone, in comparison with non-ferrous metals. Economies due to higher strength are also possible. An allowable ASME working stress of up to 23,750 psi permits reduction in vessel weight with lower unit costs.

Acceptance of 9% nickel steel in the as-welded condition by code and regulatory bodies would make this steel even more attractive to designers and fabricators since the vessel would cost less to produce without stress-relieving, and would be less expensive.

Results of "Operation Cryogenics."

Impact tests conducted late in 1960 on three full-size rectangular vessels in the as-welded condition (not stress relieved) proved they could withstand impacts far beyond any likely to occur in service. Burst tests on six cylindrical vessels, also at −320°F, showed that burst pressure for the three as-welded vessels (not stress relieved) averaged higher than that of the three stress-relieved vessels. Burst pressure for all six vessels was at least four times the design pressure. These tests proved that 9% nickel steel has the high strength, low temperature toughness, and weldability needed for cryogenic pressure vessels.

For the complete story of USS 9% Nickel Steel, including all the details of "Operation Cryogenics," write to United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

United States Steel Corporation · Columbia-Geneva Steel Division · National Tube Division · Tennessee Coal and Iron Division · United States Steel Supply Division · United States Steel Export Company

USS United States Steel

TRADEMARK

Steel For maximum strength . . . toughness . . . safety

Towering five stories high, this vertical cooling tower forms a vital part of United States Steel's spectacular new heat treating facilities shown on the next two pages. The forging is placed on a stool which can be rotated. Cooling is accomplished by the use of air or water, as required.

PLEASE LIFT FLAP

this
vital
pec-
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The
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FLAP

VOL 80

4

VOL 80

4

This mark tells you a product is made of modern, dependable Steel.

From the cradle to the lathe

New vertical heat-treating facilities handle world's largest rotors

How would you handle a forging that starts out as a 521,000-pound ingot and ends up as one of the world's largest generator rotors weighing 114 tons?

To accommodate forgings like this at its Homestead Works, United States Steel has installed seven new vertical heat-treating furnaces, a cooling tower and a unique "upender" cradle which tilts these large forgings with ease to a vertical position for crane pick-up. The new furnaces rise 25 feet above, and extend 25 feet below the floor. They can accommodate turbine and generator rotors with an overall length of 45 feet maximum and a maximum body diameter of 60 inches.

The vertical heating and cooling equipment allows large rotors to be uniformly heat treated in the upright position after they have been forged and machined.

One of the outstanding jobs for the new equipment was heat treating some of the largest generator rotors ever made. One of these is shown below being machined in the 120-inch lathe after it received its heat treatment. (The smaller rotor suspended from the crane in the big picture at the left is a different forging.)

In forgings such as these, heating and cooling operations must be carefully controlled to assure proper structure in the steel. Using the skill that only time and experience could give him, Al Sauer, a veteran in our Homestead Works, supervises the careful heat treating of these forgings. After heating, they are transferred to the 50′ high cooling tower where they are cooled at controlled rates. Then they go back for further machining, testing, boring, more heat treating, final machining, sonic inspection, and shipment.

United States Steel makes many forgings for all kinds of applications. Here, a team of experts supervises and controls every step of forging production. Let them handle *your* next order. For more detailed information about USS Quality Forgings, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

United States Steel Corporation, Pittsburgh • Columbia-Geneva Steel, San Francisco • Tennessee Coal & Iron, Fairfield, Alabama
United States Steel Export Company

Shown here are four of the seven new vertical heat-treating furnaces, housed in a modern 125 foot high building, that give United States Steel the ability to handle the largest generator and turbine rotor forgings that can be made.

One of the world's largest generator forgings being machined in our 120-inch lathe. After final machining, it weighed 114 tons.

USS TRADEMARK United States Steel

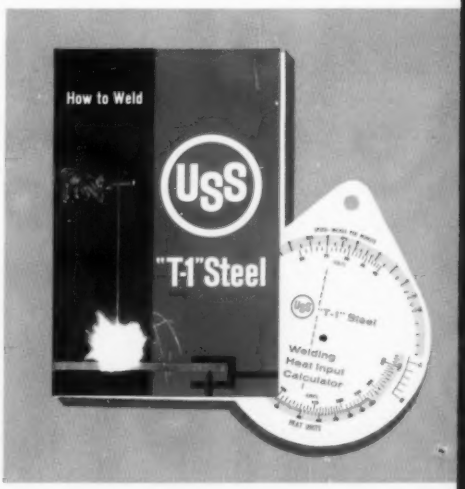
Send for new movie, "How to Weld USS 'T-1' Steels"

This new 18-minute, 16mm color motion picture shows concisely the practices involved in welding USS "T-1" Steels. If you are fabricating "T-1" Steel in your shop, this film and copies of the booklet will be a big help in demonstrating the proper technique to your welders. Fill out the coupon below and indicate the number of booklets you will need.

Included in the booklet is a handy welding heat-input calculator that helps a welder choose the proper welding machine settings. The film, together with the booklet, will help every welder to weld USS "T-1" Steels readily and successfully.

We'll gladly lend you the film and furnish enough free copies of the booklet and heat-input calculator for your shop personnel. USS and "T-1" are registered trademarks.

United States Steel Corporation • Columbia-Geneva Steel Division National Tube Division • Tennessee Coal and Iron Division • United States Steel Supply Division • United States Steel Export Company



United States Steel

USS

United States Steel, Room 6384
525 William Penn Place
Pittsburgh 30, Pennsylvania

Gentlemen:

Please lend me your 16mm color, sound movie, "How to Weld USS 'T-1' Steels." Also, send me_____booklets of the same title. I understand there is no obligation.

Name_____

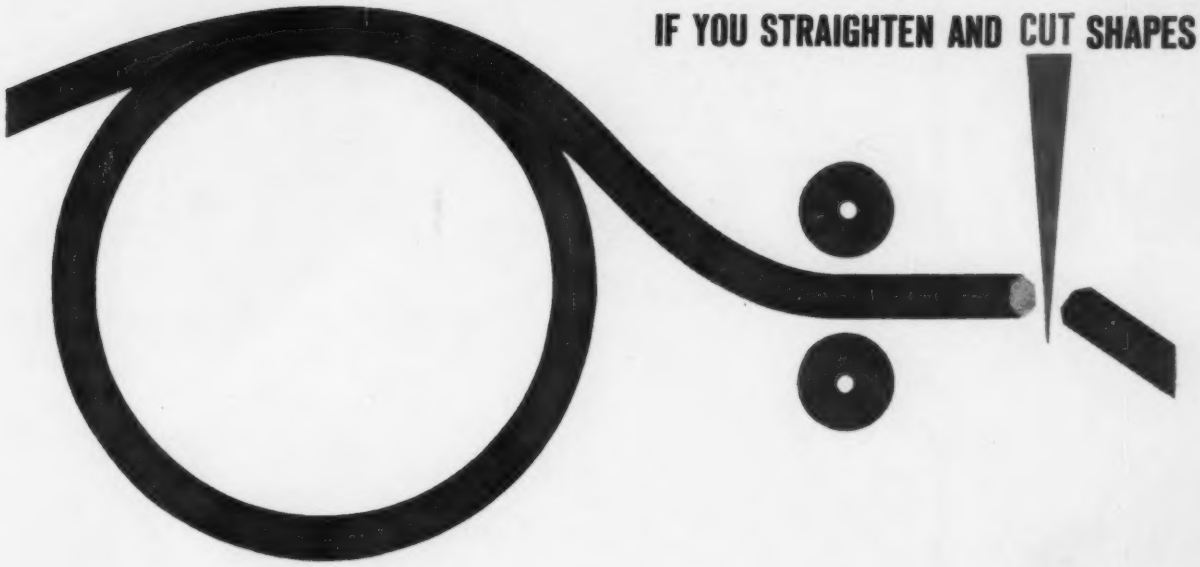
Title_____

Company_____

Address_____

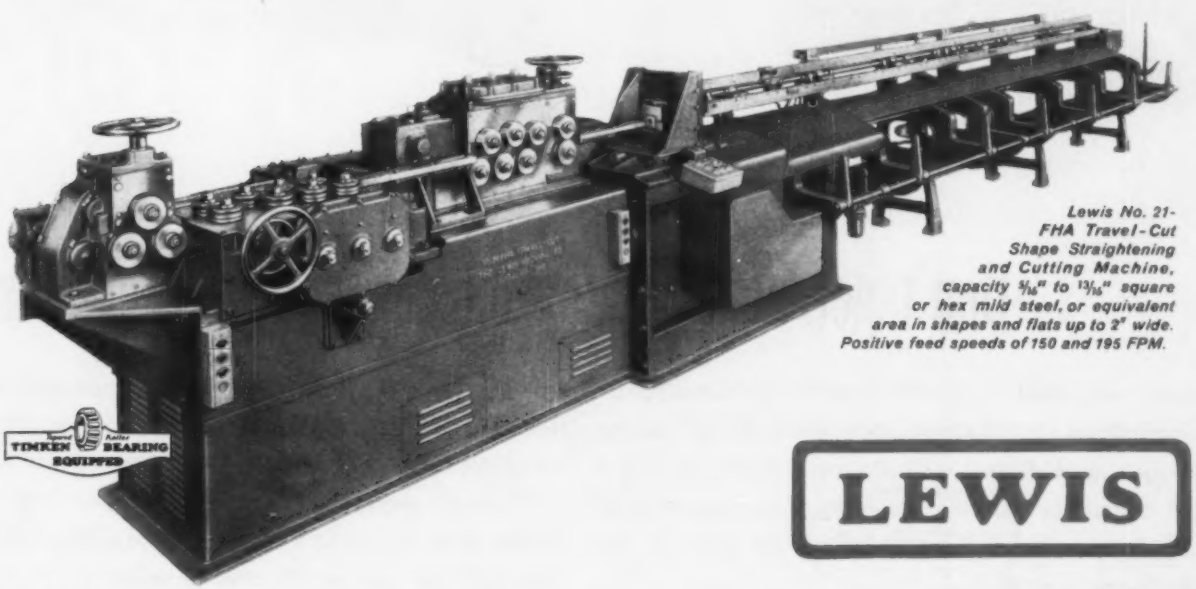
City_____ **Zone**_____ **State**_____

IF YOU STRAIGHTEN AND CUT SHAPES



You can have higher production on accurate predetermined lengths . . . direct from the coil because of these features: ■ Improved low-inertia flying-shear cutoff. ■ Simplified electric trip mechanism assures positive tripping of clutch at high speed. ■ Independent gauging mechanism permits greater accuracy and simplifies changing of cutting length. ■ All roll shafts power-driven and mounted on roller bearings. ■ Adjustable features in Horizontal Straightener Housing and Vertical Housing to compensate for various stock widths.

The Lewis Machine Company manufactures over 50 models of straightening and cutting machines to handle round wire from .012" to 1" diameter and from 1/16" to 13/16" square, hex and flat. Write or call us for information on your requirements.



Lewis No. 21-FHA Travel-Cut Shape Straightening and Cutting Machine, capacity 5/16" to 13/16" square or hex mild steel, or equivalent area in shapes and flats up to 2" wide. Positive feed speeds of 150 and 195 FPM.

LEWIS

LEWIS MACHINE COMPANY • A Division of the Curtis Manufacturing Co. • 3441 East 76th St., Cleveland 27, Ohio, MI 1-3015

Circle 1478 on Page 48-E

Don't get boxed in by oxygen supply problems...

Keep your steel operations flexible by removing all uncertainties about oxygen supply with an Airco tonnage oxygen plant. A plant we build and operate for you — on or adjacent to your site — gives you assurance of supply that only an experienced oxygen producer like Airco can guarantee.

GUARANTEED BACK-UP. Your oxygen plant is backed up by Airco's nationwide network of oxygen plants. If the plant is down for any reason, Airco will keep your oxygen flowing from its integrated system. If you need more oxygen than originally anticipated, Airco will supply whatever quantities you require. And you won't be boxed in with a rigid purchase arrangement that can't be adjusted to steel production.

PROVEN TECHNOLOGY. Making oxygen — like making steel — is a specialized business. Airco has 45 years'

let Airco build and operate a plant for you

experience in low-temperature technology . . . design, engineering and construction proficiency that has dotted the country with oxygen plants — including the first on-site oxygen plant for steel. There's no first-plant guesswork . . . late starts . . . long debugging periods that ruin your production schedules.

ASSURED LOW COST. Your oxygen is available fast . . . at a firm, fair price that reflects the economies provided by Airco's large resources and long experience.

For the full oxygen story, write, wire or phone today.

AIRCO®

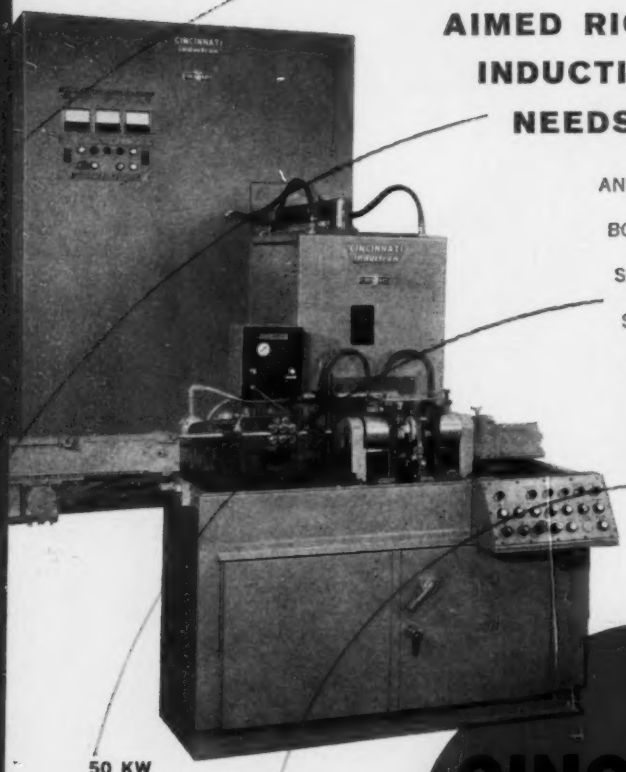
AIR REDUCTION

150 EAST 42nd STREET · NEW YORK 17, NEW YORK

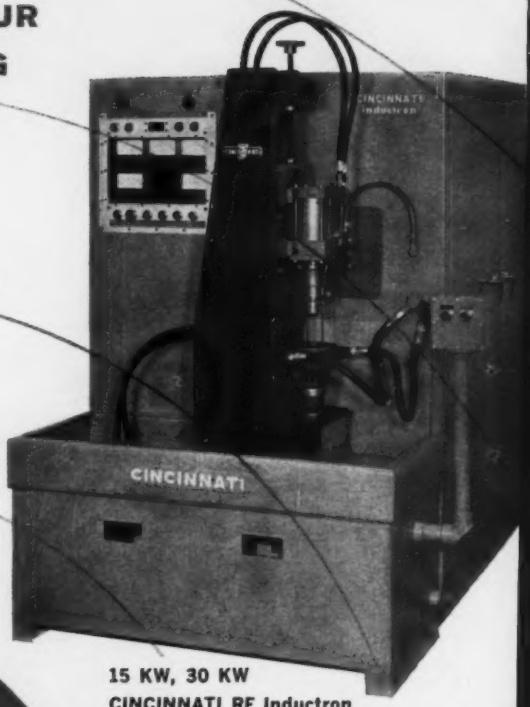
Circle 1479 on Page 48-B

AIMED RIGHT AT YOUR INDUCTION HEATING NEEDS...

ANNEALING
BOMBARDING
SELECTIVE HARDENING
SOLDERING
STRESS RELIEVING
BRAZING
SHRINK FITTING
BONDING

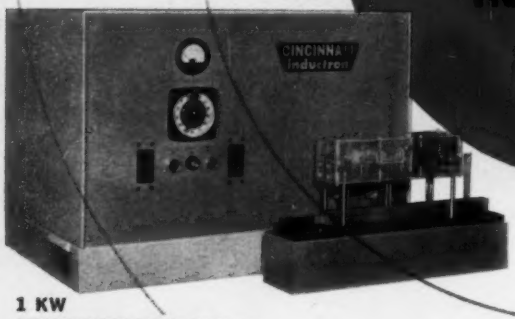


50 KW
CINCINNATI RF Inductron
450 KC frequency
Variable output transformer. Ideally suited for high speed production line operations with power station remotely located and compact work station positioned in the line.



15 KW, 30 KW
CINCINNATI RF Inductron
450 KC/1.2 MC frequencies
For automated, high production heating as well as short run work. Stepless RF output can be varied under load from 30% to 100% of machine rating.

CINCINNATI RF Inductrons IN 7 POWER SIZES



1 KW
CINCINNATI RF Inductron
450 KC frequency
Low cost, portable machine. Performs a variety of heating for manufacturing and assembling of electronic components, small instruments, jewelry.

2½, 5, 7½ KW
CINCINNATI RF Inductron
450 KC frequency.
Completely self-contained and easy-to-move unit for economical assembly line or small lot heating applications. Single or dual heating stations.

Benefit from CINCINNATI Advanced Heat Engineering!

Cincinnati RF Inductron® design gives you extremely rapid heating with positive control, plus long component life and ease of maintenance. Combined with skillfully applied work handling systems, these versatile, trouble-free Inductron machines will bring your heating operations to peak efficiency. Write us, or call a Meta-Dynamics application engineer for a detailed analysis of your requirements.

Circle 1480 on Page 48-E

META-DYNAMICS DIVISION
Center of Advanced Heat Engineering
Flame and Induction Heating Machines
CINCINNATI
THE CINCINNATI MILLING MACHINE CO.
Cincinnati 9, Ohio

NEW LITERATURE

Steel

1217. Vacuum Melted Products

Pamphlet from *Carpenter Steel Co.* sets forth the details on "Vacumeltrol" and "Consumet" vacuum melted steels and other alloys.

1218. Design Information

Booklet "Products for the Design Engineer" contains a stainless steel selector chart and data on high-strength steels, titanium, electrical steels, vacuum arc-melted steels, and other high performance metals. *Republic Steel Corp.*

1219. Alloy Steels

Bethlehem Steel Co. will send you a booklet "Quick Facts About Alloy Steels", a fundamental discussion of ferrous metallurgy.

1221. Stainless Steels

Stainless steels can give your product designs many special advantages. Catalog "Armco Stainless Steels" describes more than 50 grades. *Armco Steel Corp.*

1222. Comparison Chart

Peter A. Frasse & Co., Inc. announces the availability of a wall chart showing chemical analysis requirements for military army, navy, aeronautical, and federal alloy steel specifications. Also listed are specified forms and nearest corresponding S.A.E., A.I.S.I., and A.M.S. numbers.

1223. 17-4 PH Stainless

Armco Steel Corp. has published data on 17-4 PH stainless steel; stronger than Type 416, with corrosion resistance in the 18-8 class.

1224. Austenitic Stainless

8-p. booklet explains nature and occurrence of sigma phase, as well as its chemical composition, identification, and effect on mechanical properties and corrosion resistance. *Electric Steel Foundry Co.*

1225. Iron Powders

By using different types of carbon additives in iron-copper-carbon mixes, a broad range of dimensional control can be achieved. Data Sheet No. 3 from *Alan Wood Steel Co.*

1226. Leaded Steels

For complete information about how you can get the strength of alloy steel in free-machining steel, send for Leaded Steels catalog and Products & Facilities catalog. *Aristoloy Steels Div.*

1227. Precision Cold Extrusion

Republic Steel Corp. has released folder giving complete details on carbon and alloy steels for precision cold extrusion.

1228. Aluminum Coated Steel

Armco Steel Corp. will send pamphlets describing two hot-dip aluminum coated steels: Type 1 provides low-cost resistance to heat and corrosion; Type 2 gives products outstanding life outdoors.

Nonferrous

1230. Beta Titanium Alloy

32-p. manual on "Properties of Ti-13V-11Cr-3Al" includes data on metallurgy, design, and fabrication. *Titanium Metals Corp. of America.*

1231. Molybdenum Information

Folder gives complete listing of all information available from *Climax Molybdenum Co.* on molybdenum-base alloys and steels, irons and nonferrous alloys containing "moly".

1232. "Handbook of the Alloyist"

Discusses advantages of several groups of alloys used in the electrical and electronics industries. Properties and typical applications are given. *H. K. Porter Co.*

1233. Cobalt and Nickel-Base Alloys

4-p. data sheet lists physical and mechanical properties, corrosion resistance, thermal treatments, fabricating data, available forms, and applications of 13 alloys. *Cobalt Information Center.*

1234. Zirconium Metal

14-p. booklet "The Corrosion Resistance of Zironium" contains corrosion data for over 100 highly corrosive media in concentrations up to 100% and temperatures up to 400°F. *Zirconium Association.*

1235. Titanium for Missiles

14-p. study summarizes six major application areas for titanium in missile construction. *Titanum Metals Corp. of America.*

1236. Moly and Tungsten Products

General Electric Co. will send information on pressed and sintered molybdenum and tungsten powder metallurgy billets, slabs, tubes, or preforms made from these refractory metals.

1237. Beryllium Alloys

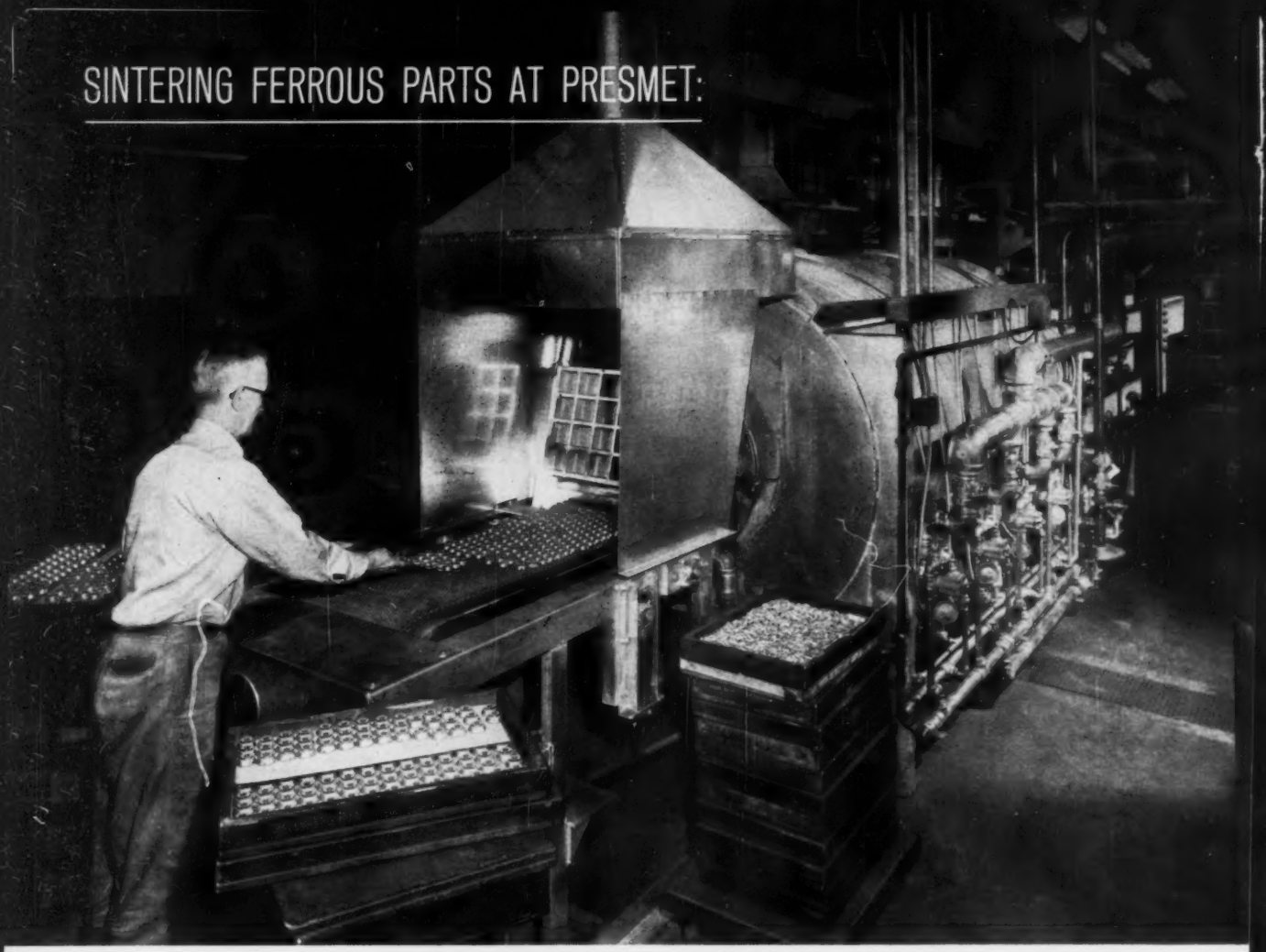
Important parts such as heavy-duty springs in submarines give more performance because of properties found in beryllium alloys. Information from *The Beryllium Corp.*

1238. "1910 Years of Beryllium"

16-p. booklet traces development of beryllium up to point where *Standard Pressed Steel Co.* is now offering first beryllium structural bolting for industry.

Circle appropriate number on Reply Card, p. 48-B

SINTERING FERROUS PARTS AT PRESMET:



dimensional stability, part strength insured

As a contract sintering specialist, Presmet Corporation of Worcester, Mass. uses this Harper Mesh Belt Furnace to sinter iron and iron graphite parts as well as to infiltrate them with brass or copper.

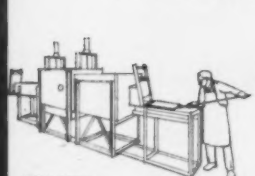
Placed on the wire mesh belt, green compacts move successively through a 1500° F gas-fired binder burnoff chamber, a volatile-vent chamber, a 2050° F high heat chamber equipped with silicon carbide elements, an insulated pre-cooling chamber and a water jacketed cooling chamber.

Designed specifically for sintering, the Harper furnace includes several unique features for positive counterflow of atmosphere gas, proper disposal of volatiles, easy ash removal, quick duplication of belt speeds, and accurate control of temperature profile.

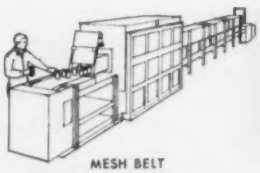
Says Presmet, "This furnace has fully measured up to expectations in maintaining product quality. With volatiles completely discharged from the vent chamber, parts emerge from cooling soot-free. A high degree of dimensional and strength control is achieved."

For detailed information on Harper Mesh Belt Sintering Furnaces such as this, request Bulletin MSF-361. Literature on other types of furnaces shown below is also available promptly. Write for one or more of the bulletins listed. Harper Electric Furnace Corp., 40 River St., Buffalo 2, N. Y.

FOR BRAZING, SINTERING, BRIGHT ANNEALING, AND FORGING IN RESEARCH AND PRODUCTION

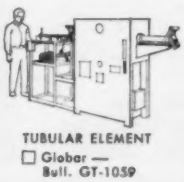


BOX TYPE
- ☐ Sintering — Bull. BFS-360
- ☐ Dry Hydrogen — Bull. HB-460



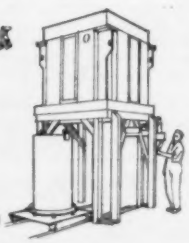
MESH BELT
- ☐ Sintering — Bull. MSF-361
- ☐ Straight Thru — Bull. MB-960
- ☐ Hump Type — Bull. HMB-960

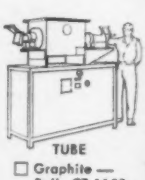
HARPER FURNACES



TUBULAR ELEMENT
- ☐ Globar — Bull. GT-1059

ELEVATOR
- ☐ Bull. EF-260





TUBE
- ☐ Graphite — Bull. CT-1159
- ☐ Zoned — Bull. ZT-361

VISIT HARPER BOOTH 433 AT THE METAL SHOW

Circle 1481 on Page 48-B

1239. Brass Alloys

A handbook on brass published by *Riverside-Alloy Metal Div.* contains data on compositions, specifications, and properties of brass wire, rod, and strip.

1240. Bronze Alloys

12-p. Bulletin G-61 lists chemistry, physical and mechanical properties, available forms and specifications for eleven types of bronzes including aluminum, tin, and manganese bronze and high conductivity alloys. *Ampco Metal, Inc.*

1241. Aluminum Ingot

"Aluminum Extrusion Ingot" published by *Alcoa* features compresensive information on extrusion ingot including data on several new alloys hitherto unavailable in ingot form.

1242. Free-Cutting Brass

Die sizes and description of "RC HEX" radius-cornered free-cutting brass hexagon rods are illustrated in catalog sheet issued by *Titan Metal Mfg. Co.*

1243. Special Metals and Alloys

Brochure "Alloys for Industry" describes specialty alloys including phosphor bronze, nickel silver, cupronickel, brass, stainless steel, nickel, Monel and Inconel. *Riverside-Alloy Metal Div.*

1244. Tin Coated Strip

Tin-coated thin strip is available in solderable coatings up to 0.0025 in. thick. on copper, brass or nickel in base metal gages from 0.002 to 0.012 in. Details from *Somers Brass Co., Inc.*

1245. Rare-Earth Metals

Bulletin from *American Potash & Chemical Corp.* contains data on rare earths in metallic forms—lanthanum through lutetium, together with yttrium.

1246. Indium Solders

"Indalloy" intermediate solders are noted for wettability, corrosion resistance, flowability and workability. *Indium Corp.* will send solder booklet.

1247. Beryllium Copper Rod

Pamphlet R-1200-A from *Beryllium Corp.* presents mechanical and physical property of three beryllium-copper alloys.

1248. Copper-Base Alloys

There is a copper alloy particularly suited to the following application conditions: corrosion, wear, high heat, extreme cold, heavy loads or impact. Bulletin from *Ampco Metal, Inc.*

Materials

1250. High-Temperature Coating

"Rokide" coatings resist heat, abrasion and corrosion at temperatures up to 4500° F.; are chemically inert and are good thermal insulators. Folder No. 361, *Coors Porcelain Co.*

1251. René 41

Technical Bulletin No. 86 discusses René 41, the most dependable alloy in use today in the 1200 to 1800° F. range. *Cannon-Muskegon Corp.*

1252. Super Refractories

The Refractories Div. has published "Super Refractories by *Carborundum*" which contains application and property data on special refractories.

1253. Corrosion Data Charts

The corrosive effects of 400 different materials on 16 different alloy systems—including Hastelloys, Monel, Nickel, Inconel, aluminum, tantalum, titanium and zirconium—are shown in data chart published by *Nooter Corp.*

1216. Vinyl-Aluminum Laminates

The *Aluminum Co. of America* has published a 20-p. brochure entitled "Design With Alcoa Vynalate" which contains

39 precoated samples in a wide range of color-pattern combinations. The booket also includes technical data on the product and suggested applications.

1254. Refractory Metal Chart

Offered by *Fansteel Metallurgical Corp.* Lists the properties of the refractory elements tungsten, tantalum, molybdenum, and columbium.

1255. High-Temperature Graphite

Speer Carbon Co. has prepared a bulletin entitled "Carbon and Graphite for High-Temperature Applications".

1256. Thermal Fatigue

Electro-Alloys Div. has published a report "The Mechanism of Thermal Fatigue", by H. S. Avery.

1257. 4100° F. Service

Bulletin PC from *Chromalloy Corp.* describes a chromallized Mo component which withstands temperatures to 4100° F.

1258. High-Temperature Alloys

Seventeen "Haynes" alloys are compared against each other in the areas of physical, mechanical and chemical properties and stress-rupture data. 20-p. booklet from *Haynes Stellite Co.*

1259. Iron Powder

Products made with iron powders provide design flexibility, reduce production costs and can be manufactured to closer tolerances. Information from *Alan Wood Steel Co.*

1260. Glassed-Metal Products

16-p. Bulletin 987 describes glassed-metal pipe, valves and fittings for installations that require resistance to corrosion or processes that cannot tolerate contamination of product. *Pfaudler Co.*

1261. Service at 2300° F.

Electro-Alloys Div. has issued pamphlet containing data on "Supertherm", a 26% Cr, 35% Ni alloy for service in 1800 to 2300° F. range.

1262. Corrosion-Resistant Alloys

Haynes Stellite Co. is offering a 104-p. book which discusses "Haynes" corrosion-resistant alloys, their properties, forms, and the corrosives they will resist.

1263. Tungsten Sheet and Plate

Tungsten sheet and plate is now available in 24 in. widths and thicknesses from 0.150 to 0.500 in. Information from *General Electric Co.*

1264. Heat Resistant Castings

The International Nickel Co. will send 72-p. booklet "Heat Resistant Castings, Corrosion Resistant Castings . . . Their Properties and Applications".

1265. High-Alloy Castings

Brochure from *The Fahralloy Co.* discusses static, precision shell molded, or centrifugal castings in stainless, high-temperature and special alloys.

1266. Refractory Cement

Quality of any high-purity metal can only be as good as the quality of refractory cement used to contain it. Information from *Norton Co.*

1267. Diamond Knives

DuPont Co. offers pamphlet detailing the advantages of diamond knives which boast unusually fine edge equality.

1268. Refractory Metals

Get the full story on refractory metals produced as pressed and sintered products. Ingots, bars and shapes can be produced by this method. *Sylvania Electric Products Inc.*

Tooling

1270. Automatic Forging

The "Model C" impacter with a program controlled feed device makes possible automatic forging. Bulletin 110-L-1, *Chambersburg Engineering Co.*

1271. Colloidal Graphite

To learn more about unique advantages of colloidal graphite in your industrial applications, send for literature from *Acheson Colloids Co.*

1272. Tool Steel Selector

Three "Steelector" cards and a bulletin will help you in selecting specific tool steel grade that will suit 96% of all tool steel applications. *Allegheny Ludlum Steel Corp.*

1273. Dry-Film Lubricants

Reprint and data sheet present information on inorganic solid-film lubricant performance in extreme environmental service. *Alpha-Molykote Corp.*

1274. Ceramic Tooling

Vascoloy-Ramet Corp. has published three bulletins discussing applications for cutting-tool material, "Ceramic VR-97".

1275. Grinding Coolant

A fluorescent green aqueous compound is now available for grinding and honing ferrous alloys. Literature from *Baker/Gubbins Co.*

1276. Impact Extrusions

Engineering Manual No. FM-3019 discusses impact extrusions in aluminum, copper, brass and alloy steels. *Mueller Brass Co.*

1277. Wire Coilers

The "Rotobloc" operating at the end of your wire processing lines assures uninterrupted flow and lower production costs. Details from *Vaughn Machinery Co.*

To request any item listed circle appropriate number on Reply Card, p. 48-B

Carbon/Graphite Facts for METALLURGISTS

NATIONAL TRADE MARK

INJECTION and FLUXING TUBES
for ferrous and non-ferrous metal treatment

FOR use in degassing non-ferrous metals, or for the injection of graphite powders beneath the surface of molten iron, NATIONAL graphite tubes provide the most satisfactory material. They resist thermal shock, are non-contaminating, and have no affinity for metal or dross. Tubes are stocked in a wide range of sizes for immediate shipment.

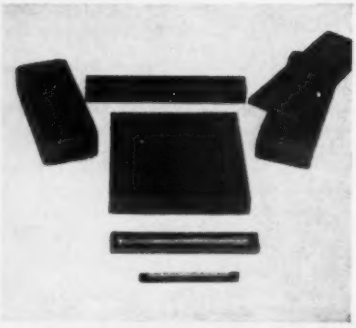
Circle No. 1424 on Page 48-B

GRAPHITE POWDERS
give fast, high-rate recovery and primary control at low cost

NATIONAL graphite powders—ranging in size from very fine flour to coarse particles—are available for a wide variety of applications. Fineness and maximum ash content are held within closely controlled limits. A few uses include: injection or inoculation of ferrous metals, mold washes, powder glazing, lubricants, and powder metallurgy applications. For complete list and specifications, request Catalog Section S-7655.

Circle No. 1425 on Page 48-B

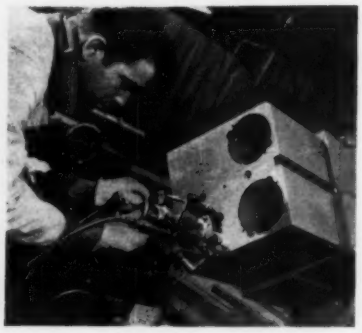
HEAT TREATING ACCESSORIES
Boats, Trays, Jigs, Discs, and Plates



HEAT treating accessories of NATIONAL graphite provide a combination of advantages not found in other materials. They are longer lasting, non-contaminating, and will not warp, crack or soften in use. Special shapes are easily machined to close tolerances. Among the many uses for these graphite accessories are: powdered metal and carbide sintering, zone refining, furnace brazing, fusion of elements into semi-conductor wafers, and other furnace processing.

Circle No. 1426 on Page 48-B

MACHINING
of graphite is a skilled operation at NATIONAL CARBON



MACHINING to close tolerances is a regular practice of NATIONAL CARBON. Graphite can be turned, sawed, bored, milled, drilled, planed, shaped, ground, tapped, reamed, honed, or lapped. Whatever your requirements—simple or intricate shapes—NATIONAL CARBON's strategically located plants have the equipment and skilled craftsmen to meet your most rigid specifications. Contact us . . . graphite may also solve your problems.

Circle No. 1427 on Page 48-B

"National," "Union Carbide," "N" and Shield Device are registered trade-marks for products of

NATIONAL CARBON COMPANY
Division of Union Carbide Corporation • 270 Park Avenue, New York 17, N. Y.
IN CANADA: Union Carbide Canada Limited, Toronto

UNION CARBIDE

Heating

1279. Heating by Induction

56-p. catalog sets forth details on induction heating equipment for hardening, brazing, soldering, forging, annealing, melting, sintering and welding applications. *Induction Heating Corp.*

1280. Miniature Thermocouples

Bulletin No. 4336 describes line of micro-miniature thermocouples, world's smallest and fastest temperature sensors. *Baldwin-Lima-Hamilton Corp.*

1281. Quenching Data

Texaco Co. has prepared a booklet "Quenching and Hardening" which contains information on steel heat treating.

1282. Heat Treating Chart

Tempil Corp's four-color chart, "Basic Guide to Ferrous Metallurgy", illustrates forging, burning, annealing, transformation, stress-relieving, nitriding, blue brittle, normalizing, and carburizing ranges, as well as grain size changes vs. temperature.

1283. Radiation Thermometer

Pamphlet R-103 describes the "Model TD-6 Thermodot" which measures and controls temperature without contact. *Radiation Electronics Co.*

1284. Tool Steel Identification

The *Gorham Tool Co.* has published a 26-p. booklet covering classifications and symbols for identification of high-speed steels.

1285. Tool Steel Guide

Written by B. L. Averbach of M.I.T., "Toolsteels", a basic guide to the use of tool and die steels, has been published by *Climax Molybdenum Co.*

1286. Thermocouple Alloys

Catalog-Manual from *Hoskins Mfg. Co.* contains information on entire family of Chromel - Alumel thermocouple grade alloys, plus much helpful technical application data.

1287. High-Temperature Furnaces

Marshall Products Co. will send literature on vacuum furnaces for operation at temperatures up to 4000° F.

1288. Precision Pyrometer

Daystrom, Inc. has published brochure discussing the "Model 8800 Sensitrol" pyrometer — an instrument for critical temperature control applications. Accuracy, 0.5% full scale; sensitivity, ±0.1%.

1289. Heat Treating Equipment

For information about a full line of electric or fuel-fired industrial furnaces and ovens, contact *Hevi-Duty Electric Co.*

1290. Pneumatic Temperature Transmitter

The Foxboro Co. has prepared Bulletin 13-17C discussing "Type 12A" pneumatic temperature transmitter· illustrates how easily transmitter can be installed and adjusted to suit a wide range of uses.

1291. Automatic Control

Folio 122, a 24-p. catalog of industrial heating furnace control systems, has been published by *GPE Controls, Inc.*; covers automatic control for open-hearth furnaces, glass tanks, reheating and annealing furnaces and soaking pits.

1292. Resistance Alloy

8-p. brochure describes properties and performance characteristics of Alloy 750, a low-growth iron-chromium-aluminum resistance material for use in heating elements operating up to 2050° F. *Hoskins Mfg. Co.*

1293. Furnace Tubes

Pamphlet from *The Pressed Steel Co.* explains all-sheet construction of furnace tubes to minimize burnout and add to tube life.

1294. Potentiometers

The "Electronik 17" potentiometers have no slide wire and therefore no slide wire problem. Get the facts from *Minneapolis Honeywell.*

1295. Synthetic Coolant

E. F. Houghton & Co. will send complete data on "Hocut 3210", a highly fortified water-soluble concentrate which has outstanding anti-weld and extreme pressure characteristics.

1296. Continuous Carburizing

Surface Combustion Div. has released pamphlet detailing the advantages of processing parts with continuous gas carburizing furnaces.

1297. Induction Hardening

Induction hardening boosts production up to ten times. *Ohio Crankshaft Co.* will send pamphlet "Typical Results of Tocco Induction Hardening and Heat Treating".

1298. Quench Oil Coolers

Catalog and simplified selection manual from *Bell & Gossett Co.* details the advantages of "Hydro-Flo" oil quenching systems.

1299. Optical Pyrometer

Bulletin No. 614 describes "Pyro-650", an automatic optical brightness pyrometer for measuring, recording and controlling temperatures from 1200 to 6300° F. *Instrument Development Laboratories.*

1300. Heat Processing

If you heat treat springs, fasteners or gears, there is a *Sunbeam Equipment Corp.* furnace to do the job more efficiently at less cost. Brochure available.

1301. Sintering Furnaces

C. I. Hayes, Inc., will send brochure which presents the facts on sintering furnaces for cermets, ceramics, refractory metals or stainless steel powders. Temperatures to 3300° F.

1302. Thermocouple Applications

The Bristol Co. has released a 56-p. Users' Manual which contains complete data on thermocouple applications and pyrometer accessories.

1303. Quenching Oils

Brochure covers a complete range of quenching oils to meet every processing requirement. *Sun Oil Co.*

1304. Atmosphere Furnaces

Pamphlet from *Harrop Precision Furnace Co.* supplies details on line of Kanthal-Super" atmosphere furnaces with maximum temperatures up to 3000° F.

1305. Proportional Controller

4-p. Bulletin 16 from *Thermo Electric Co.* describes straight-line temperature control with a proportional controller to minimize overshoot cycling.

1306. Bright Annealing

The Electric Furnace Co. will send information on furnace equipment for bright annealing of stainless strip.

1307. Heat Treating Line

Drever Co. offers continuous wide plate heat treating line which can harden and temper plate at the rate of 32,000 lb. per hr.; information available.

1308. Gas Alloying

Lee Wilson Engineering Co. has published information on open-coil gas alloying of nonaging rimmed steels — to replace aluminum-killed steel.

1309. Precision Furnaces

Bulletin from *Perenv Equipment Co.* gives the facts on a complete line of pre-

Circle appropriate number on Reply Card, p. 48-B

Straits Tin Report

Tin-lined copper tube recently developed combines tin's corrosion resistance and malleability with the strength and ductility of copper. Pure molten tin is gas-propelled through the tubing to form a continuous, fusion-bonded tin lining that will not chip, crack or peel, and can be

Photo courtesy Phelps Dodge

bent, flared, flattened or soldered. Tin provides immunity to corrosive sulfur conditions found in some natural gas and petroleum products; affords excellent resistance to flaking action that can plug lines and orifices and create hazards with gas appliances. The tin lining also prevents contamination of fluids in process lines of food, beverages, pharmaceutical and water distilling equipment and for sampling lines to laboratory or control instruments, according to its producers, Phelps Dodge Copper Products Corp.

Acid pickling of steel before hot tinning produces maximum bond strength of bearing metal to steel. Shot blasting preparation lowers bond strength, possibly because of distortion, folding and flowing during precleaning.

FREE Brochure

16 interesting pages of information about the latest uses of tin in U.S. industry. Write today for your copy.

The Malayan Tin Bureau

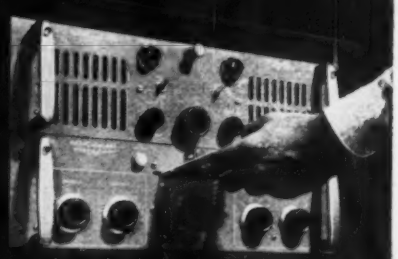
Dept. S-25J, 2000 K St., N.W., Washington 6, D.C.

Circle 1483 on Page 48-B

Now! "On the mill" eddy current inspection

BUDD RADAC 440

with precise, punched-card programming



Budd's new model 440 Radac now enables precise, automatic eddy current inspection to be applied under production-line conditions by production-line personnel. Proved in a wide range of "on the mill" installations, the Radac 440 can be used to detect surface and internal cracks, seams, laps, splits, holes, inclusions, weld defects and other types of discontinuities . . . in tubing, bars, flat stock and many other shapes over a wide dimensional range. All types of metals can be inspected. New saturation accessory allows testing of ferrous as well as non-ferrous metals. Results are independent of variations in dimensions, wall thickness, temperature, chemical composition, residual stresses and other variables.

The Radac 440 is an advanced, multiple-frequency eddy current flaw detector programmed by punched card. Only general knowledge of eddy current principles is required for reliable operation. With the punched cards accurately defining inspection requirements, responsibility for reproducibility of results is placed in the instrument . . . thereby greatly reducing the possibility of human error.

The Radac 440 features a striking array of exclusive new features in addition to punched-card programming. Full information on the 440 and other versatile Radac equipment is yours on request. We'll be glad to demonstrate Radac eddy current inspection in your plant.

INSTRUMENTS Budd DIVISION

THE BUDD COMPANY • P.O. Box 245 • Phoenixville, Pa.
Consult your phone book for sales offices in: Atlanta, Ga.; Chicago, Ill.; Dallas, Texas; Detroit, Mich.; Los Angeles, Calif.; Seattle, Wash.
In Canada: Budd Instruments, Ltd., 170 Donway West, Don Mills, Ont.
Other countries: Budd S.A., 10 Avenue de la Grande Armée, Paris 17e, France

Visit us at Booth 220 at the Metal Show, Oct. 23-27
Cobo Hall, Detroit

cision furnaces for controlled atmosphere treating at temperatures from 1300 to 2900° F.

1310. Heat-Treating Equipment

Catalog 607 from *American Gas Furnace Co.* covers complete line of equipment and accessories for every type of metal heat treating.

Finishing

1312. Chemical Milling

16-p. brochure from *Eastman Kodak Co.* describes "Metal-Etch Resist", a chemical milling process which speeds up weight-reduction jobs and parts manufacture.

1313. Surface Treatments

Conversion Chemical Corp. will send you a fact sheet containing details on 40 products including chromate coatings and bright dips for ferrous and nonferrous alloys.

1314. Electroplating Processes

24-p. Bulletin EP-102 discusses 18 electroplating processes, including three new nickel plating operations. *Hansen-Van Winkle-Munning Co.*

1315. Plating Supplies and Equipment

R. O. Hull & Co. has released a catalog describing complete line of plating supplies, equipment, and instrumentation for the plating industry.

1316. Cleaning of Steel

Booklet entitled "Three Essential Steps in Cleaning Steel Before Electroplating" available from *Oakite Products, Inc.*

1317. Diamond Wheels

The *Norton Co.* has released a brochure which contains information on diamond wheels and diamond hones.

1318. Buffing and Polishing

20-p. technical manual covers manual or semiautomatic polishing, burring, satin finishing, buffing and high coloring of metals, plastics, wood and organic coatings. *Lea Mfg. Co.*

1319. Rust Control

8-p. guide to controlling rust during production operations has been incorporated into a rust-control data file, offered by *Magnus Chemical Co.*

1320. Chemicals for Electronics Field

Fidelity Chemical Products Corp. has issued a folder on chemicals for the electronics industry . . . bright dips, carbon removers, cleaners, scale removers, wire strippers, and ultrasonic descalers.

1321. Pre-Paint Treatment

"Cryscoat" zinc phosphate pre-paint treatments provide lasting corrosion resistance beneath paint under all kinds of heavy punishment. Bulletin F-8979, *Oakite Products, Inc.*

1322. Gaging Coatings on Aluminum

Brochure published by *Twin City Testing Corp.* introduces "Type EC Permascope" for nondestructive measurement of nonconductive coatings on nonferrous base metals.

1323. Wet Blasting

Pamphlet entitled "Precision Finishing Operations Where You Can Cut Costs by Wet Blasting" has been issued by *Lord Chemical and Equipment Div.*

1324. Glass Shot

"Glas-Shot" are microscopic glass beads for use with all types of wet or dry blast equipment. Details from *Microbeads, Inc.*

1325. Pre-Treating Aluminum

Amchem Products, Inc. has published a brochure discussing application of "Alodine" pre-paint treatment on aluminum by roller coating.

1326. Anode Plating Chemicals

Hanson-Van Winkle-Munning Co. has made available an 8-p. bulletin illustrating a full line of anodes, anode accessories, and chemicals for electroplating and metal finishing.

1327. Electrocleaner

"Oakite 190" a reverse current cleaner removes smut, rust, and soil in one operation. Pamphlet from *Oakite Products, Inc.*

Welding

1329. Welding and Brazing

56-p. catalog and instruction manual covers welding, brazing, soldering and fluxes. Properties, uses and application data included. *All-State Welding Alloys.*

1330. "Guide to Better Welds"

80-p. booklet discusses causes and cures of common welding troubles, essentials for proper welding, and electrode selection. *Hobart Brothers Co.*

1331. Welding Stainless

Information concerning techniques for welding stainless steel is contained in

Circle appropriate number on Reply Card, p. 48-B

Charge components of the ferrous alloys we cast are measured frequently in split ounces. Molding sand is tested for properties every hour. Each heat, from each of the 6 electric furnaces, is laboratory tested — certain checks are made even *before* pouring is permitted.

Process control rigidly checks every step of production from receipt of raw materials through final inspection, assuring strict adherence to the tightest specifications — metallurgical, physical and dimensional.

Samples representative of every heat are subjected to chemical analysis. Castings for unusually critical applications often require specialized tests — partial or 100% X-ray inspection, ultra-sonic testing for internal defects, and others. These are provided.

Yet, with all these deterrents to speed, we have produced 150,000 castings a day — day after day.

If you need "prescription counter" accuracy in the make-up of your castings, we would appreciate an interview.

LICENSED PRODUCERS OF NI-HARD, NI-RESIST, DUCTILE IRON, AND DUCTILE NI-RESIST

EI

ENGINEERING CASTINGS, INC.

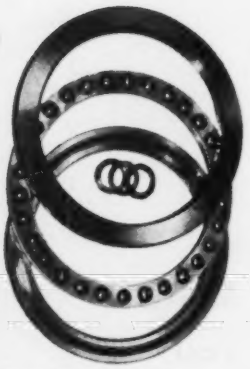
MARSHALL, MICHIGAN

Circle 1485 on Page 48-B

You Can't Beat an AJAX *Cataract*® Quench (ISOTHERMAL) ...for

. . . Day-in, day-out uniformity accuracy and reproducibility

. . . Freedom from cracks, distortion and surface defects

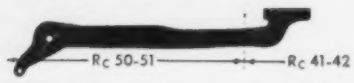


Critical hardening without distortion

Ajax isothermal heat treating reduced finish grinding 50% on these 52100 precision ball thrust bearing races by minimizing distortion and surface defects.

Taming a heat treater's "nightmare"

This 11⅜" diameter Vasco B.B. steel valve plate varies in section thickness from ½" to 1⅜". Ajax isothermal treatment hardens thin sections to Rc 63-64 and thick sections to Rc 60-64.



Automatic selective austempering

Fully automatized austempering of typewriter bars plus selective salt bath draw assures Rc 50-51 hardness at fulcrum ends and Rc 41-42 for 1" at type ends. Production was increased 65%, rejects reduced 45%.

PROVIDES ANY NEEDED QUENCH VELOCITY

. . . FROM NOTHING TO NIAGARA!

Results from the Ajax Cataract Isothermal Quench are outstandingly accurate and uniform. Toughness and ductility are increased. Cracks, distortion and surface defects are virtually eliminated.

These advantages result from inherent characteristics of the method. The Cataract Quench *heats* automatically below the control point, *cools* above it. Quench direction and flow velocity are easily and effectively controlled to meet practically any requirement. Chemical balance between quenching salts and "dragged in" heating salts is automatically maintained.

Write for Ajax Bulletin 700 for details.

AJAX ELECTRIC COMPANY
910 Frankford Ave., Philadelphia 23, Pa.

SEE AJAX . . .
Booth 452
Metal Show

Foreign Licensees: Master Argentina, S.A., Buenos Aires, ARGENTINA
Birlec Major Proprietary Ltd., Victoria, AUSTRALIA
Organicacao Industrial Fides, S.A., Sao Paulo, BRAZIL

Circle 1486 on Page 48-B

Lincoln Electric Co. Bulletin 7300.2 entitled "Arc Welding Stainless Steel".

1332. Nickel Alloys

Wall Colmonoy Corp. has issued Data Sheet T-1 which discusses relative corrosion resistance of "Colmonoy" nickel alloys.

1333. Silver Brazing

Bulletin 20 gives a good picture of silver brazing and its benefits; includes details on alloys, heating methods, joint design and production techniques. *Handy & Harman.*

1334. Silver Brazing Alloys

24-p. manual released by *Air Reduction Sales Co.* covers brazing procedures, problems and solutions. A complete range of brazing alloys is discussed.

1335. Electron Beam Welder

The "E-Beam Mark VI" electron welder makes possible welding and brazing of many refractory and reactive metals. Data from *Alloyd Electronics Corp.*

1336. Semiconductor Fabrication

Semi-Alloys Inc. offers data sheets on aluminum, gold, indium and silver alloys for semiconductor fabrication.

1337. Welding Periodical

Vol. 5, No. 9 of a 16-p. welding periodical issued by *Sciaky Bros., Inc.* reports on practical methods of profitable assembly with fusion, electron beam and resistance welding techniques.

1338. Electronic Tracer

Simple pencil-line sketches of intricate shapes can be used to guide shape-cutting machine with an electronic tracer; described in leaflet prepared by *Linde Co.*

1339. Pipe Welder

4-p. leaflet released by *Air Reduction Sales Co.* describes equipment for automatic welding of pipe using CO_2 welding process.

1340. Paste Solders

Flyer from *Fusion Engineering Co.* describes "G & W" paste solders . . . stable combinations of solder alloy, flux, and binders.

1341. Vapor-Shielded Arc Welding

Lincoln Electric Co. has released Bulletin No. 5300.1 which describes vapor-shielded arc welding and the new semi-automatic "Innershield Squirt" and full-automatic "Innershield" welders.

1342. Multi-Welder

Pamphlet from *Hobart Bros. Co.* details the advantages of the "Multi-Wire" welder for all semiautomatic processes. including micro-wire, MIG-CO_2, MIG-argon, submerged arc, and open-arc welding.

1343. Flame Spraying

Linde Co. will send details on equipment for flame-plating with tungsten carbide or other powdered materials for temperature and wear-resistant uses.

Testing

1358. Research Microscope

The "Dynoptic" metallurgical microscope lets you study opaque specimens by your choice of bright field, dark field, or polarized light — with critical resolution of fine detail. Catalog D-1053, *Bausch & Lomb Inc.*

1359. Disk Indicators

Detailed information on its line of disk indicators (used in measuring and control systems employing resistance strain-gage transducers) is contained in brochure offered by *Baldwin-Lima-Hamilton Corp.*

HIGH TEMPERATURE!
IMPERVIOUS!
ALUMINA!
MULLITE!

CERAMIC
PROTECTION TUBES

High temperature atmosphere and vacuum furnace muffle tubes! Radiant heat treating furnace tubes! Pyrometer protection tubes! Diameters to 10"; lengths to 72" depending on ceramic body. For temperatures to 3000° F; higher in smaller sizes.

Write for information today!

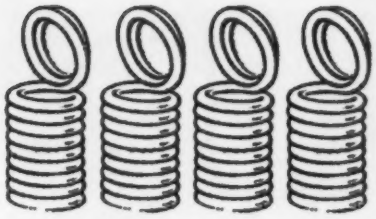
McDANEL Industrial CERAMICS

McDANEL
REFRACTORY PORCELAIN COMPANY
BEAVER FALLS · PENNSYLVANIA

Circle 1487 on Page 48-B

The Porter Alloyist delivers the right alloy IN THE SPOTS THAT COUNT

Circle 1498 on Page 48-S



In a split second, the parachute will leap from the pack, released by five special stainless steel springs. Can you think of a tougher spot for reliable performance? Now—and every other time—the springs must work *perfectly*, must keep their shape, unfailing strength and resistance to low temperatures. It's a job for exactly the *right alloy*—recommended and supplied by the Porter Alloyist.

THE PORTER ALLOYIST IS A SPECIALIST IN A WIDE RANGE OF SPECIAL METALS

Porter's Riverside-Alloy Metal Division is your single reliable source for specialty alloys in 8 basic groups of wire, rod and strip . . . phosphor bronze, nickel silver, cupro nickel, brass, stainless steel, nickel, Monel and Inconel.

Ask for a free copy of "Alloys for Industry" describing our wide range of specialty alloys. Write H. K. Porter Company, Inc., Riverside-Alloy Metal Division, Riverside, N. J. Or contact our sales offices in Hartford, Chicago, East Orange, Atlanta, Cleveland, Detroit, Cincinnati, Los Angeles and Rochester.

PORTER cupro nickel wire carries the workload in telephone switchboards.

PORTER supplies bronze and brass strip for wiring harnesses in automotive and marine electrical systems.

PORTER

RIVERSIDE-ALLOY METAL DIVISION
H. K. PORTER COMPANY, INC.

1360. Analytical Instruments

28-p. catalog contains specification and operating data on seven key instruments for research and production control. *Philips Electronic Instruments.*

1361. Industrial Sensors

4-p. brochure describes how optical, infrared, magnetic, electromagnetic, and nuclear devices are used to inspect, control, measure, validate and detect in many process operations. *Designers for Industry, Inc.*

1362. Literature Searching

8-p. pamphlet discusses electronic system for searching technical articles, documents and patents on metals and related subjects. *American Society for Metals.*

1363. Research Metallographs

American Optical Co. will send details on the "AO Metallograph", a laboratory workhorse which is dependable and versatile.

1364. Mounting Press

Buehler Ltd. has prepared leaflet covering the "Powermet" press for rapid mounting of metallurgical samples.

1365. Instrument Charts

Brochure G100-6 from *Minneapolis Honeywell* contains information on instrument charts available in 3, 4 and 12 in. widths and circular charts in 8, 10 and 12 in. diameters.

1366. Hardness Testing

Catalog RT-58 from *Wilson Mechanical Instrument Div.* gives complete information on superficial tester as well as on a full line of Rockwell hardness testers.

1367. Spectrographic Analysis

The "Compact Atomcounter" is simple to operate; one technician can analyze up to 150 samples per day for 10 or more elements. Details from *Jarrell-Ash.*

1368. Carbon Determination

Bulletin 2051 from *Illinois Testing Laboratories, Inc.* covers the "Dewpointer", an instrument for determining carbon potential in furnace atmospheres.

1369. Advanced Testing Techniques

Instron Co. has prepared a series of articles on universal testing machines and on other advanced testing techniques covering many fields.

1370. Flaw Detector

The "Model 424-D Immerscope" ultrasonic flaw detector boasts outstanding flexibility and many new features including A-Scan presentation and exceptional sensitivity. Details from *Curtiss Wright, Princeton Div.*

Casting

1388. Manganese in Aluminum

In binary alloys, manganese improves strength of aluminum by 20% with no sacrifice in corrosion resistance. Write for article "Manganese Puts Muscle in Aluminum" from *Union Carbide Metals Co.*

1389. Vacuum Furnaces

Richard D. Brew and Co. will send information on a complete range of high-temperature cold-wall vacuum furnaces which will operate at temperatures up to 2500° C.

1390. Liquid Oxygen Cylinder

A liquid oxygen cylinder with a capacity of 3000 cu. ft. is described in booklet now available from *Linde Co.*

1391. Vacuum Pumps

32-p. Catalog 561 gives complete data on rotary positive air pressure and high-vacuum pumps, as well as gas booster and air motors. *Leiman Bros., Inc.*

1392. Hydrogen Generation

Bulletin No. 511 "Metal Hydrides for Hydrogen Generation" describes how metallic hydrides can be used for generation of hydrogen through interaction with water. *Metal Hydrides, Inc.*

1393. Ceramic Gating Components

Catalog from *Universal Clay Products Co.* covers all standard ceramic gating components produced by the company.

1394. Cleaning of Castings

Pangborn will send information on "Rotoblast" machines for the almost completely automatic cleaning of castings with practically no need for maintenance or repairs.

1395. Heat Treatment of Stainless

24-p. research report "Heat Treatment and Properties of Cast, Hardenable Stainless Steels" is offered by *WaiMet Alloys.*

1396. Electrical-Grade Steels

Electrolytic manganese contains only traces of carbon, sulfur, oxygen and nitrogen, all of which are detrimental to electrical properties. Bulletin 201 details advantages of electromanganese additions. *Foote Mineral Co.*

1397. Vacuum Melted Products

Carpenter Steel Co. will send details on "Vacumeltrol" and "Consumet" vacuum melted metals for higher quality products.

1398. Infrared Analyzers

Prevent damaging oxidation and change in carbon content of metal surfaces by measuring H_2O, CO_2, and methane with an infrared analyzer. Details from *MSA Instrument Div.*

1399. Flux Additive

By using "MCA" flux you make large rimming ingots and maintain deep-drawing quality of small ingots. *Molybdenum Corp. of America.*

1400. Th-Mg Master Alloy

Vitro Chemical Co. will send pamphlet discussing thorium-magnesium master alloys as well as other pure metals of the rare-earth family.

1401. Mold Coating

Leaflet describes applications of "Spuncote 7" as a readymade mold coating for centrifugal gray-iron castings. *Foseco, Inc.*

Parts

1403. Precision Fine Wire

Fort Wayne Metals, Inc. has released brochure which contains information on precision fine wires in stainless and other alloys including composite materials.

1404. Quality Tubing

Superior Tube Co. will send article "Nondestructive Testing of Small Tubing" as well as technical data on 120 analyses of small-diameter tubing.

1405. Wire Cloth

120-p. catalog from *Cambridge Wire Cloth Co.* discusses a complete range of wire cloth products.

1406. Precision Tubing

Bulletin No. 12 from *J. Bishop & Co.* describes precision tubing up to 1 in. O.D. in stainless, nickel, super and exotic alloys.

1407. Spring Pins

8-p. product manual published by *Standard Pressed Steel Co.* presents data on "Sel-Lok" spring pins and includes design and performance information.

Circle appropriate number on Reply Card, p. 48-B

SONOTONE

uses Armour anhydrous ammonia to "clean" electronic tube components

At Sonotone's Tube Division, grids, connectors, plates—*all* metal tube components are passed through an atmosphere derived from Armour ammonia. In this cleaning operation, dissociated ammonia removes oxides and flushes out other vaporized impurities.

Why Ammonia?

Because it costs so much less than hydrogen. In cylinders, less than half as much. In bulk, about one-fourth!

When you're saving as much as $10.00 per 1,000 c.f. of atmosphere, you soon recover the cost of a dissociator. Then, too, consider the safety and storage factors. With ammonia, the only flammable gas present is the gas you're *using*. Ammonia storage equipment does not present a flammable safety hazard.

Dryness of the atmosphere is important, too. With dissociated ammonia, a dew point of —60°F. can be obtained without drying equipment.

Why Armour?

Says Sonotone's maintenance supervisor, Jack Richardson: "We know from ten years' experience that we can depend on the high purity and uniform quality of Armour ammonia. Also, we know we can count on Armour's expert technical service."

When you buy Armour ammonia, you have no doubts about purity. Every cylinder, every tank truck is tested, *after filling*, to make sure the ammonia is at least 99.98% pure when delivered.

Another advantage: Fast delivery from 171 distribution points across the country. See your Yellow Pages for the stock point nearest you.

AMMONIA SALES: Cylinder, Tank Truck, Transport and Tank Car Service

Armour Industrial Chemical Company

One of The Armour Chemical Industries

110 North Wacker Drive • Chicago 6, Illinois

Circle 1489 on Page 48-B

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS

NONFERROUS METALS

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES

WELDING AND JOINING EQUIPMENT AND SUPPLIES

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS

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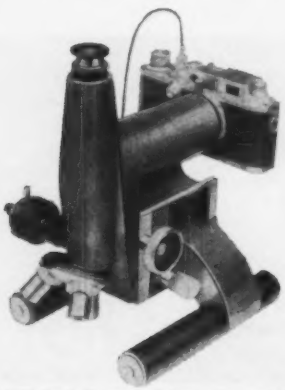
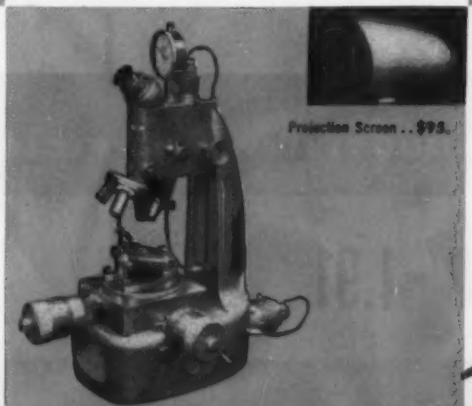
Binocular Inverted Model BMEC with camera mechanism.....$615.
Monocular Inverted Model MEC.....$399.
(Polaroid Land Camera attachment available)

Model MMA.....$149. Model MMU.....$287.

Binocular Metallograph BU-11.....$1379.
Monocular Metallograph U-11.....$1195.
Polaroid Land Camera attachment.....$116.



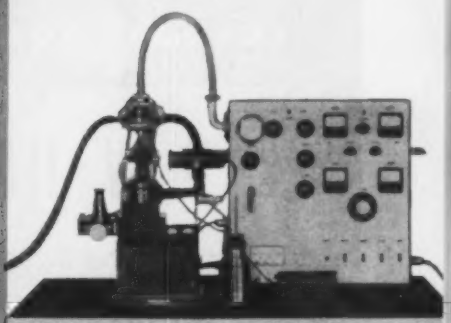
Model DMR Depth-Measuring Rollscope for examination of large or cylindrical surfaces.....$445.



Projection Screen..$95.

Toolmakers and Metallurgical Microscope Model TM for 3-dimensional measuring.....$1050.
(other models available)

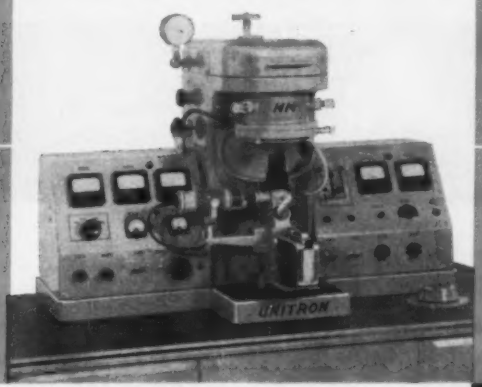
UNITRON'S Complete Laboratory Installation for High-Temperature Metallography with Metallograph and HVC-3 Control and Power Station.



Stereoscopic Model MSL.....$110.

Stereoscopic Model MSM with turret changer.....$320.

UNITRON'S Research Installation for High-Temperature Microscopy, Desk Model HM
(Write for price and complete specifications)

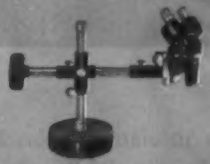


HNS-3 Vacuum Heating Stage for 1500° C.....$625.

Long Working Distance Objective FF40X.....$149.

Goniometer Eyepiece from $53.

Stereoscopic Model MSHL with revolving nosepiece.....$267.



Pillar Stand for Stereoscopic Models.....$75.

Austenite Grain Size Eyepieces:
Turret-Type..$76.
Ke 10X.....$25.

Filar Micrometer Eyepiece..$69.50

Stage Micrometer $11.

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to meet every metallurgical application . . . from low-power macro to high-power micro examinations, right on through to advanced research in high temperature studies of the new metals in the space age. And when it's time to balance your equipment budget against your needs, UNITRON prices will be among the best news of all.

TRY A UNITRON IN YOUR LAB . . . FREE, FOR 10 DAYS

A salesman's demonstration gives you only about 30 minutes to examine a microscope . . . hardly the best conditions for a critical appraisal. But, UNITRON'S Free 10-Day Trial allows you to use the microscope in your own lab and put it through its paces on your own particular problem. Use the coupon to ask for a no-obligation, prepaid trial. And if you want more details on these and other UNITRON Microscopes, use the coupon to request a complete catalog.

Circle 1408 on Page 48-B

UNITRON
INSTRUMENT COMPANY • MICROSCOPE SALES DIV
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Another *plus* of Lightweight B&W Insulating Firebrick

LOWER THERMAL CONDUCTIVITY means

THERMAL CONDUCTIVITY COEFFICIENT*

B&W · IFB · 1.91

Competitive IFB · 3.04

NOTE: The above chart, based on available published figures, compares the difference in thermal conductivity between lightweight B&W IFB and the average of seven other leading insulating firebrick. This example, specifically covering 2300 F use limit insulating firebrick, is representative of the low conductivity of B&W IFB at all temperature levels.

*BTU/SQ. FT./IN. THICKNESS/HR./DEG. F.

All insulating firebrick are not the same. Published figures show wide variations in *all* of the important properties among the leading brands of IFB.

Take thermal conductivity. This important property affects fuel costs, temperature control and the speed with which a furnace heats and cools. Thermal conductivities range from a B&W low of 1.91 to a high of 3.47 for a competitive IFB—*almost a 100% difference in wasted heat and fuel costs.*

You are paying for insulating firebrick . . . make sure you get *all* the benefits. B&W—the originator of IFB—manufactures a full line of IFB with an experience-proved balance of light weight, high insulating value, high strength and long life.

For complete information on B&W Insulating Firebrick, write for Catalog R-38 to The Babcock & Wilcox Company, Refractories Division, 161 East 42nd Street, New York 17, N. Y.

NUMBER 1 OF A SERIES

LOWER FUEL COSTS

the payoff

- 14% lower fuel costs • 30 F lower casing temperature
- 25% less time to reach operating temperature • 12 hours saved per cycle

These are the results of a direct comparison of two furnaces of the type shown above, one lined with B&W IFB and the other with one of the better competitive insulating firebrick. That's how B&W pays off for a major steel company in their 8-stack, hood type, strip annealing furnaces. This is just one of many proofs in our files that "there is an important difference in insulating firebrick."

B&W

R-659

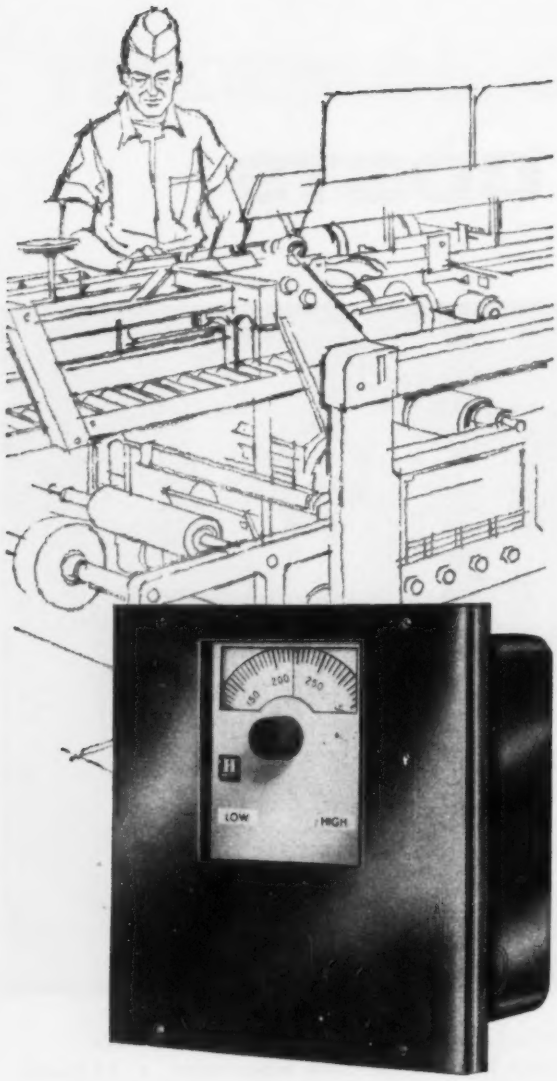
THE BABCOCK & WILCOX COMPANY

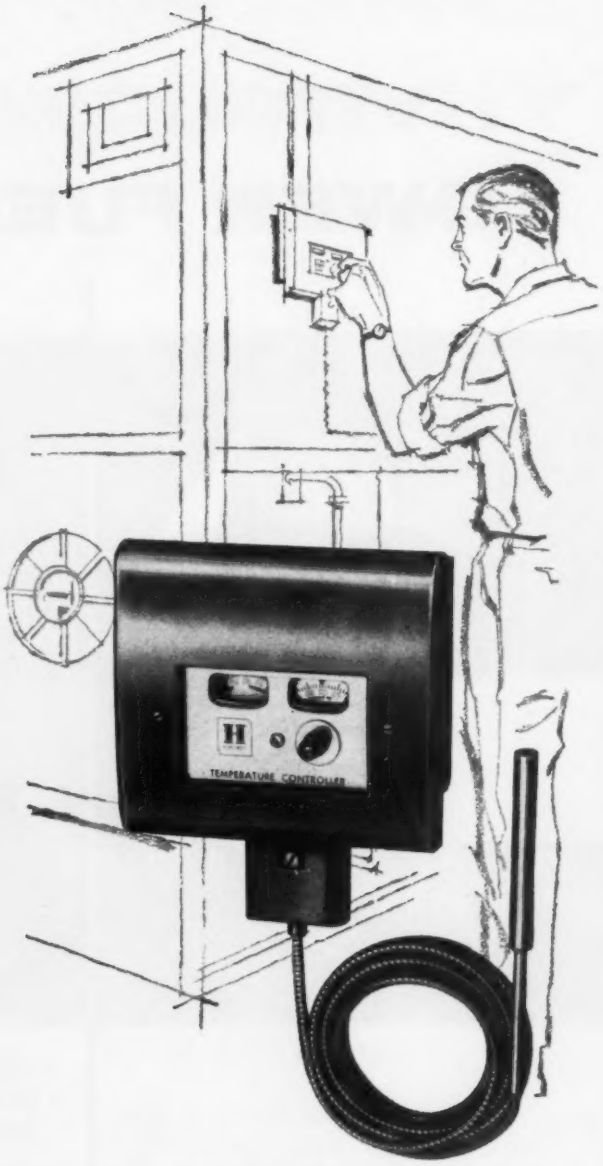
REFRACTORIES DIVISION

Circle 1409 on Page 48-B

Whether you choose by specification, price or both...

There's a Honeywell pressure control





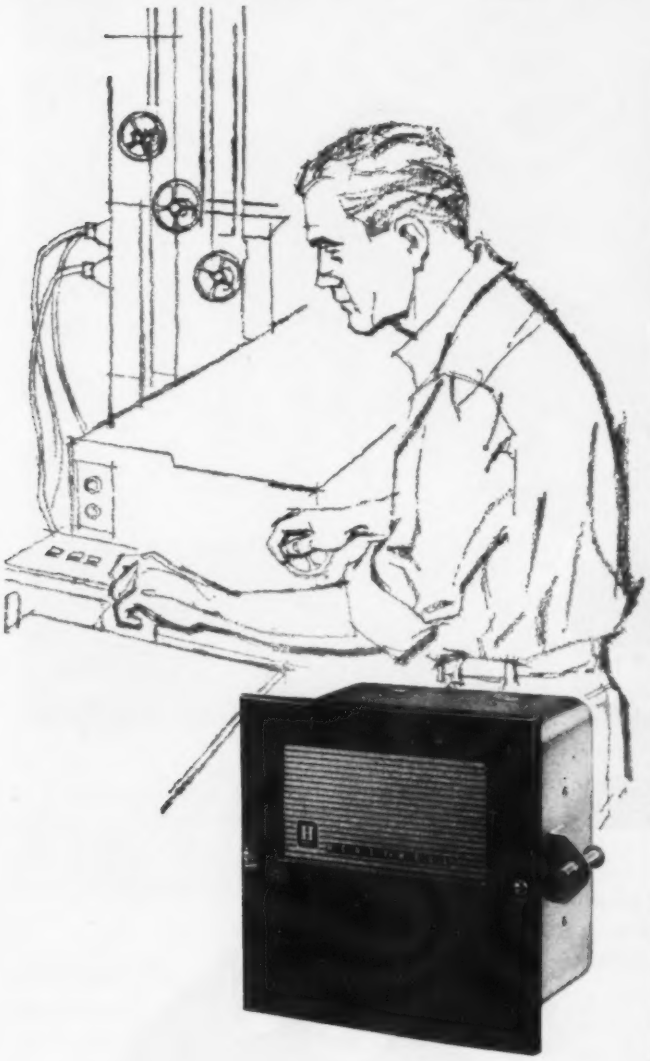
☐ **For precise control at low cost—R7086—R7087**

Temperature controllers for use wherever precision temperature control must be maintained. Ranges from −150° to +3000° F. are possible. R7086 uses thermocouple, R7087 uses resistance bulb. Both, surface or flush mounted. R7086 $150.00; R7087 *only $120.00.*

☐ **For accurate control with indication at low cost**

T654A indicates and controls temperatures on an evenly graduated scale accurate within 1% of scale range. This switch can control an *Actionator**, motor, relay, contactor or other device. Completely compensates for ambient temperature changes. Ranges from −150° F. to 1200° F.

temperature or to fit your exact needs!



☐ For reliable control at minimum cost—VERSA-TRAN

This inexpensive controller is completely transistorized. Needs no tubes, no warm-ups . . . gives instant reaction. Works with sensors that can be thermisters, probes, resistance bulbs, pressure transducers or humidity elements. Available in various temperature, humidity and pressure ranges. *Standard models as low as $39.50.* Model shown above only $49.50.

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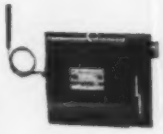
P444

For industrial applications that call for independent high-pressure and low-pressure settings and switching action. Adaptable for surface or flush mounting.



T444

For a wide variety of industrial applications requiring independent high-temperature and low-temperature settings and switching action. Adaptable for surface or flush mounting. Ranges from 0° F. to 660° F.

P428

For general industrial applications requiring the control or limiting of relatively high pressures. Models are made with explosion-proof case for hazardous locations. Ranges from 30 PSI to 5000 PSI.

T667

Designed for use as a remote-bulb temperature controller. SPDT switching provides temperature control in heating, cooling, or heating-cooling commercial and/or industrial applications. Ranges from −150° F. to 1200° F.

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First in Control

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Circle 1410 on Page 48-E

1470 AB

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A New, Wet Hand Grinder for Metallurgical Samples

Now you may have wet grinding facilities for hand preparation in your laboratory at a nominal cost. Convenience at your fingertips, always clean and ready for use. Simply attach to water and drain facilities.

Individual elevated hard glass grinding surfaces are continually flushed with streams of water. This floats off the surface removal products, provides lubrication, and leaves sharp abrasive edges exposed at all times. A control valve permits complete selectivity of the volume of water. Ample drainage facilities with standard pipe fittings are provided at the rear. The grinding platforms are pitched downward and away from the operator.

The Handimet Grinding Paper is coated with a pressure sensitive adhesive backing and firmly holds when merely pressed against the flat grinding surface. It is easily removable when sheet is worn.

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exhibit at the Metal Show
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Circle 1411 on Page 48-B

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DURACOAT® FOR:

Zinc • Cadmium • Aluminum • Copper • Brass • Clear, Bright, Irridescent • Golden, Olive Drab

SALT BATHS for all heat treating jobs from 300°F. to 2500°F.

Neutral Hardening • Liquid Carburizing • Tempering • Annealing — Ferrous and Non-Ferrous • Austempering and Martempering • Liquid Nitriding • High-Speed Hardening • PreHeat and Quench Salts • Copper and Silver Brazing • *Scale-free! Clean! Bright!*

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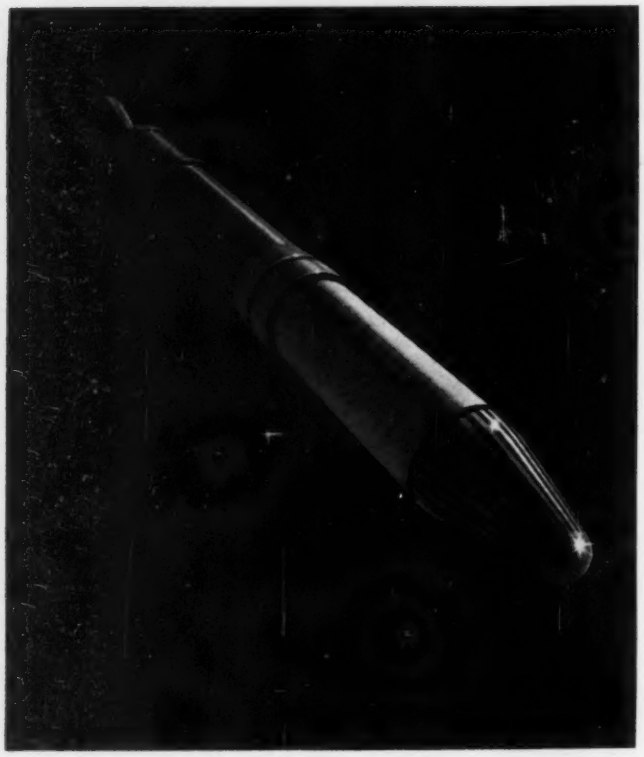
Prompt shipment from stocks in Springfield, Chicago, Cleveland, Detroit, Los Angeles and Sanford, N. C. *In Canada,*

W. J. Michaud, Ltd., Montreal.

Circle 1412 on Page 48-B

DESTINATION: 500,000 PSI

Republic is a major supplier of titanium in the Mercury Project. The titanium—AMS4901—is used in the vehicle's double wall stringer construction.



New steels for space with tensile strengths even beyond 500,000 psi are the target of Republic research.

In the development, unwanted microscopic inclusions of foreign matter like the one circled (magnified 19,000 times by the electron microscope) are studied, analyzed, and identified.

To permit thorough analysis, these inclusions are carefully removed from surrounding steel. How? By a drill small enough to put two holes, side by side, across the thickness of a *human hair*.

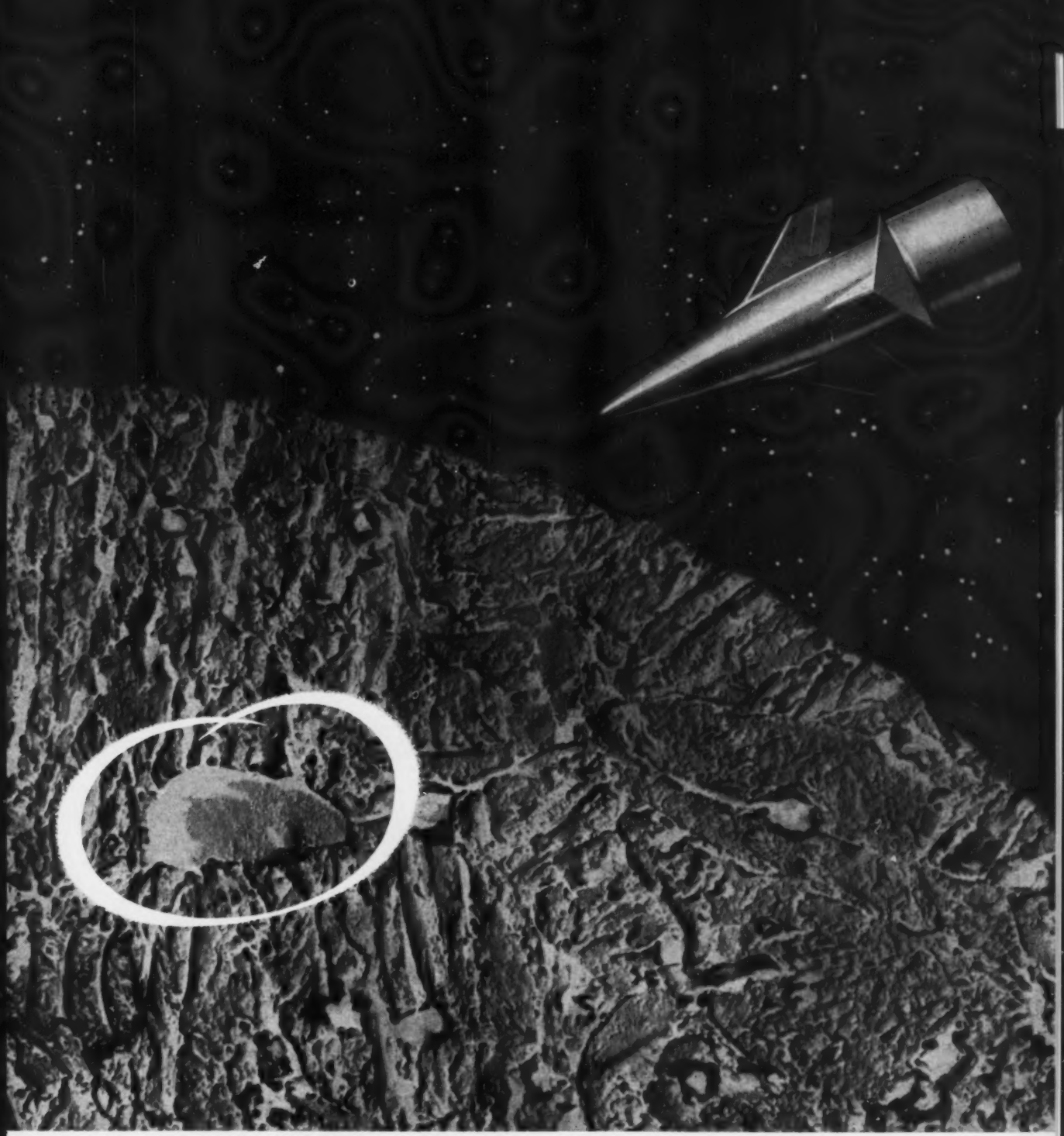
Largest producer of stainless and alloy steels, Republic has one of the most extensive vacuum melting capabilities in the world. And it is the purification by vacuum melting that substantially increases the strength and reliability of steels for space.

A new source for Precipitation Hardenable Stainless Steels . . . the *only* source of continuous rolled stainless sheet up to 60 inches wide . . . Republic offers expert metallurgical service. For information, contact your nearest Republic sales office or mail the coupon.

DESIGN ENGINEERS: Mail the coupon for a copy of Republic's new booklet, *Products for the Design Engineer*. Contains a useful Stainless Steel Selector Chart, and information on Republic High Strength Steels, Titanium, Electrical Steels, Vacuum Arc Melted Steels, and other high performance metals.

Strong, Modern, Dependable

Type 430 Republic Stainless Steel was used by the Lodge and Shipley Company in fabricating the nose cone for Explorer I. The Flotorn process was utilized to produce specified deviations in wall thickness.



REPUBLIC STEEL

REPUBLIC HAS THE FEEL FOR MODERN STEEL

Circle 1413 on Page 48-B

REPUBLIC STEEL CORPORATION
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1441 REPUBLIC BUILDING · CLEVELAND 1, OHIO

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I would like more information on:

- ☐ Alloy Steels
- ☐ ENDURO® Stainless Steels
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Have a metallurgist call:

- ☐ Alloy Steels
- ☐ ENDURO Stainless Steels
- ☐ Titanium
- ☐ PH Stainless Steels

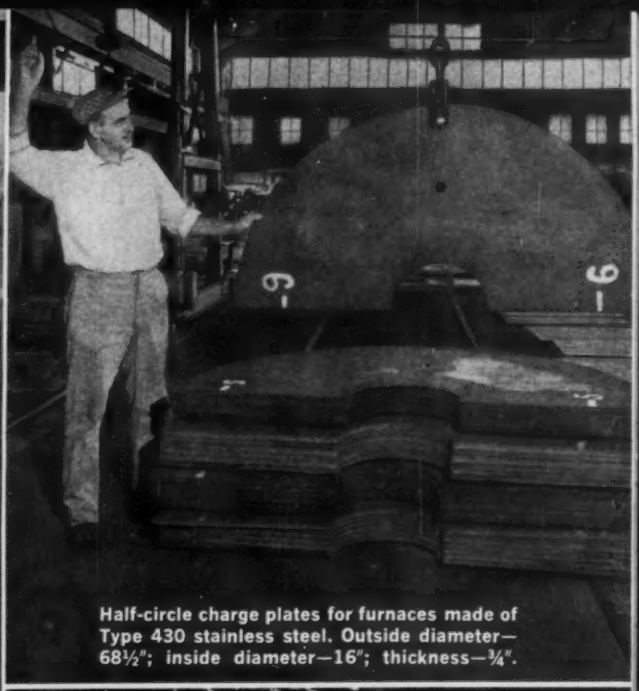
Name_____ Title_____

Company_____

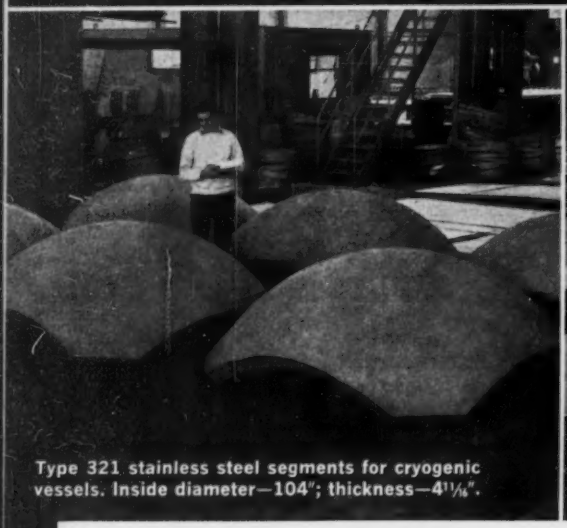
Address_____

City_____ Zone_____ State_____

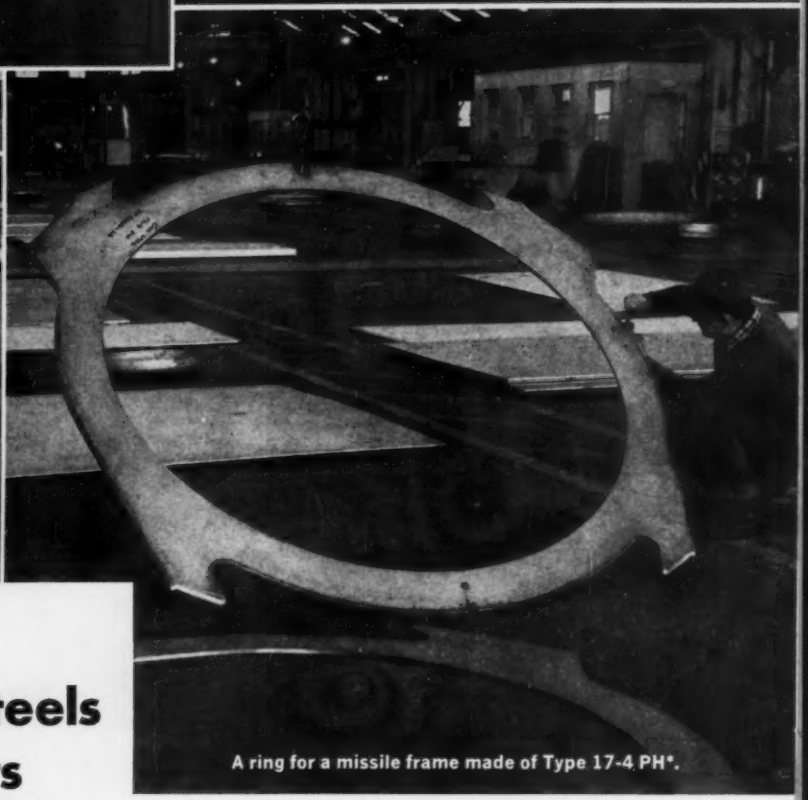
Indexing plate for nuclear storage cask. Type 304. Outside diameter—44⅛"; thickness—2¼".



Half-circle charge plates for furnaces made of Type 430 stainless steel. Outside diameter—68½"; inside diameter—16"; thickness—¾".



Type 321 stainless steel segments for cryogenic vessels. Inside diameter—104"; thickness—4¹¹⁄₁₆".



A ring for a missile frame made of Type 17-4 PH*.

special shapes special stainless steels for special projects

Producing stainless steel plate, plate products, and forgings is our business. Orders often call for unusual shapes in stainless plate, shapes that will become important components in special projects. Whatever the requirement, your confidence in Carlson specialists is well placed.

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Plates • Plate Products • Heads • Rings • Circles • Flanges • Forgings • Bars and Sheets (No. 1 Finish)

Circle 1414 on Page 48-B

VAUGHN® MOTOBLOX®

dependably draw

unique ALUMOWELD® *wire*

Heavy, pure aluminum, inseparably atomic-welded to a strong steel core—that's Alumoweld wire, used extensively today in the power and communications fields. And all of this valuable product is drawn rapidly, economically and dependably on VAUGHN Motoblox machines—whether destined for use as telephone line wire, overhead ground wire, core wire for ACSR conductors, guy and messenger strand or other essential and money-saving applications. ● Whatever the wire, rod, bar or tube, there's a VAUGHN machine to draw it profitably. Write us!

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Cuyahoga Falls, Ohio, U.S.A.

COMPLETE COLD DRAWING EQUIPMENT . . . Continuous or Single Hole . . . for the Largest Bars and Tubes . . . for the Smallest Wire . . . Ferrous, Non-Ferrous Materials or their Alloys.

Circle 1415 on Page 48-S

Would you take a chance on a sure thing?

Make your next welder a P&H!

HARNISCHFEGER
Milwaukee 46, Wisconsin

P&H
WELDING PRODUCTS DIVISION

Circle 1416 on Page 48-S

DURAFLEX

the more durable, ductile, flexible phosphor bronze—at no extra cost

Here is one of the most versatile of phosphor bronzes. The superfine-grain structure of Duraflex provides a considerable improvement in fatigue life over regular phosphor bronze. Now you can obtain higher endurance limits with greater formability. It's ductile. It's resilient. It's corrosion-resistant!

This new, higher quality Anaconda phosphor bronze is now available in several standard phosphor bronze alloys—in strip metal up to 0.062″ thick and up to 14″ wide in all standard tempers, and in wire up to 5/16″ diameter. Duraflex strip is also available in long rolls.

Within the capabilities of size and alloy composition, Duraflex strip and wire can be applied to the innumerable uses for which conventional phosphor bronzes are employed, and in most instances provide longer and more efficient service. *Yet Duraflex sells for the same price as regular phosphor bronze in the same alloys and forms.*

Publication B-38 tells the story. Write for your copy—or for any assistance from our Metallurgical Dept. in selecting the proper alloys for your metalworking projects. Address: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 61-1148

DURAFLEX®

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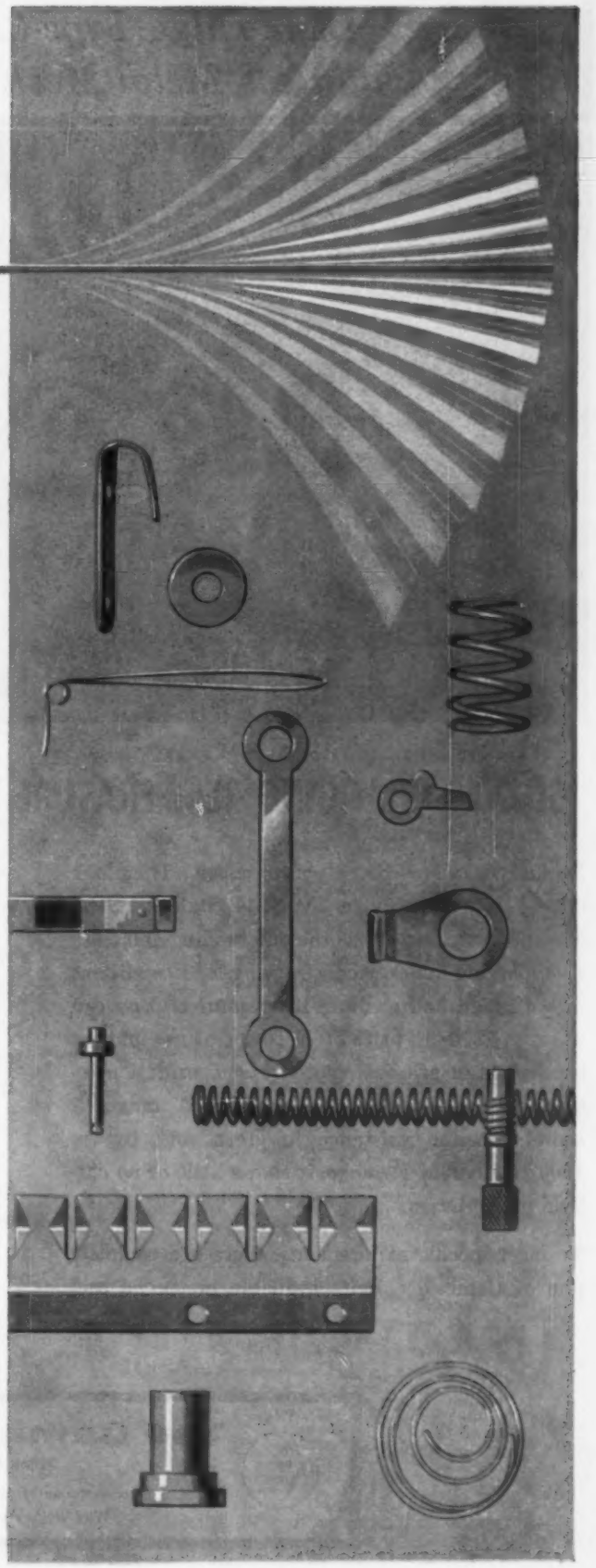
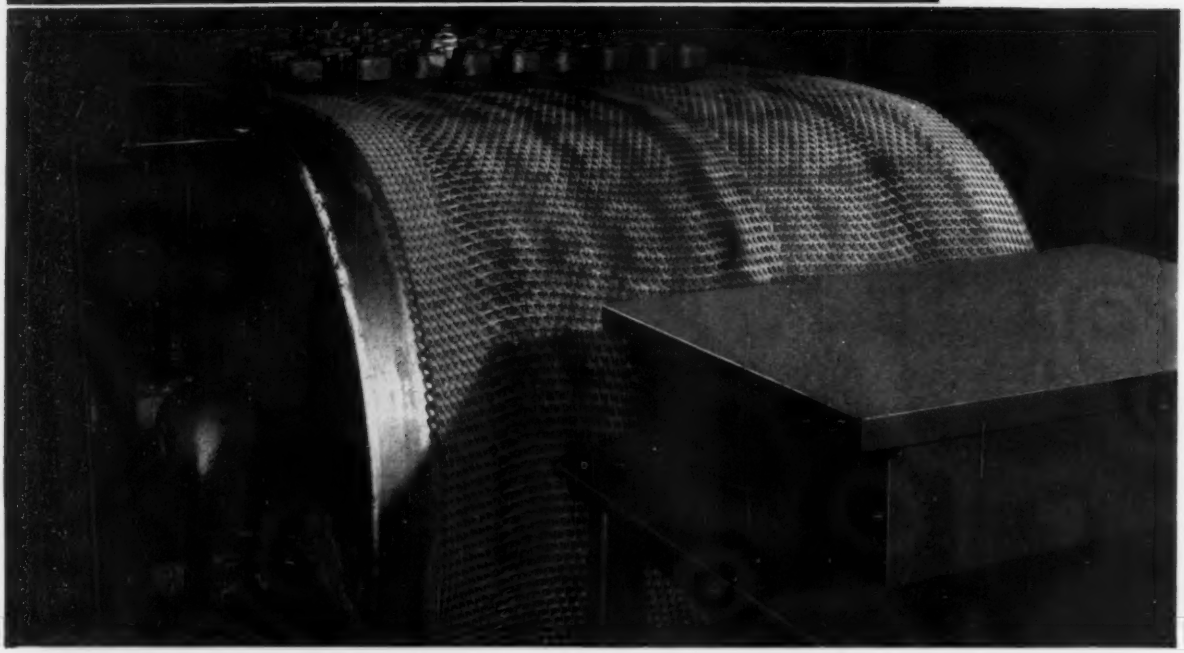
AMERICAN BRASS COMPANY



Circle 1417 on Page 48-B

Cambridge Type-314 Stainless Metal-Mesh Belt



SOLVES CHANGING TEMPERATURE, CHANGING LOAD PROBLEMS

Looking for a low-cost, all-purpose belt? Then look closely at a Cambridge Type-314 Stainless Steel Metal-Mesh Belt. It has the outstanding ability to give long life under widely varying load conditions in both high and medium temperatures. You can use it in 2100° F. to 1850° F. temperatures and get excellent strength characteristics and oxidation resistance. In the 1850° F. to 1600° F. range, it shows superior resistance to green rot. In the 1600° F. to 900° F. range, it shows little or no carbide precipitation.

To meet specific requirements, there is a complete line of Cambridge Belts available in special and standard metals and alloys—custom built in any weave to insure the most efficient processing.

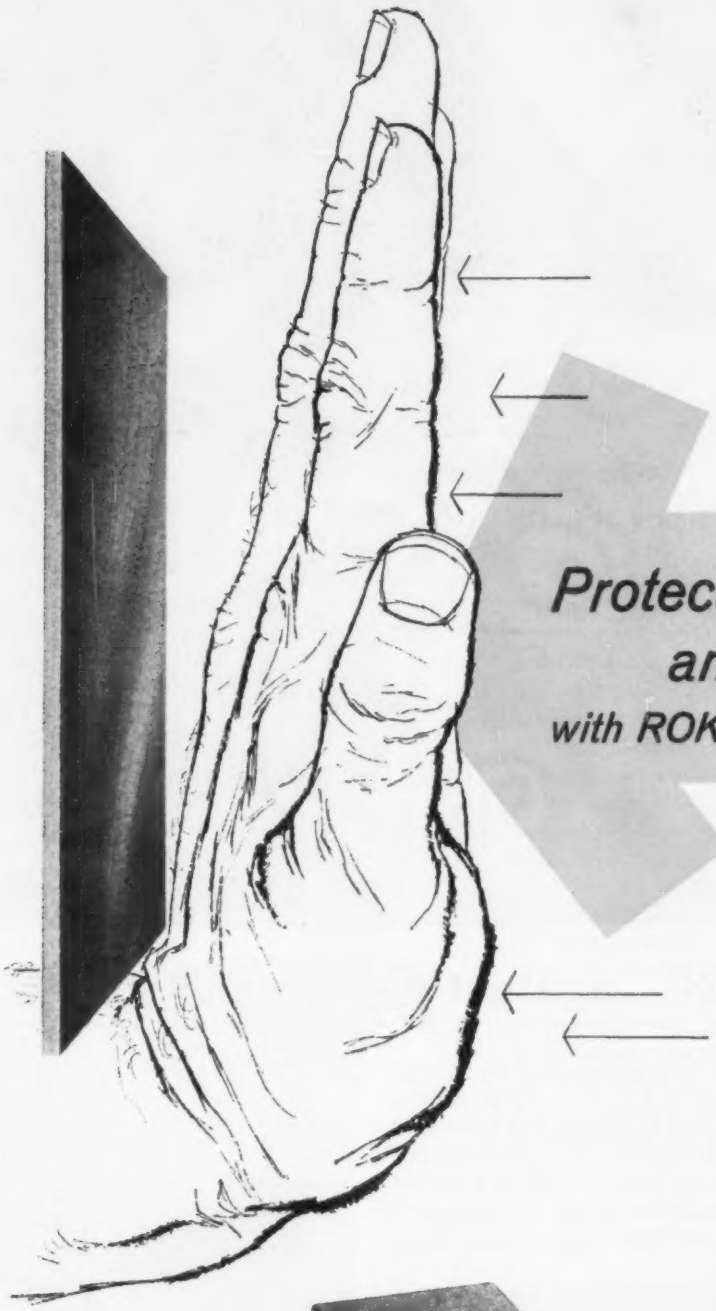
Experienced Cambridge Field Engineers—experts in their field—are available to discuss your needs and help you select the belt best suited to your operations. Or, they can offer you sound advice on the installation, operation and maintenance of your Cambridge Belts. Talk to your Cambridge man soon. He's listed in the Yellow Pages under "Belting, Mechanical". Or, write for free 130-page reference manual.

The Cambridge Wire Cloth Co.

DEPARTMENT B • CAMBRIDGE 10, MARYLAND

Manufacturers of Metal-Mesh Conveyor Belts, Flat Wire Conveyor Belts, Wire Cloth, Wire Cloth Fabrications, Gripper® Metal-Mesh Slings

Circle 1418 on Page 48-S



Here's the fast, economical way to protect vital parts and equipment against temperatures up to 4600°F . . . extreme abrasion . . . electrical energy . . . erosion and corrosion. Apply ROKIDE Ceramic Coatings — hard, crystalline refractory materials which provide *effective* protection.

ROKIDE Coatings are supplied in rod form as "Z" Zirconium Oxide, "A" Aluminum Oxide, "C" Chrome Oxide, "ZS" Zirconium Silicate, and "MA" Magnesium Aluminate. To apply, rod is heated and the molten particles projected at high velocity against the prepared surface, where they adhere and solidify.

ROKIDE Coatings are used for both military and industrial applications such as: missile components, bearing surfaces, extrusion dies, furnace and feed rolls, induction coils, igniter tips, strain gages, buffing fixtures, mechanical seal rings, pump shafts, capstan wheels, impellers, crucibles, etc.

ROKIDE Coatings are available from a number of strategically located job shop applicators or direct from Norton Company, Worcester, Mass., and Santa Clara, California. Find out how they can cut *your* maintenance and production costs. NORTON COMPANY, 329 New Bond Street, Worcester 6, Massachusetts.

*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries.

Protect modern metals and materials

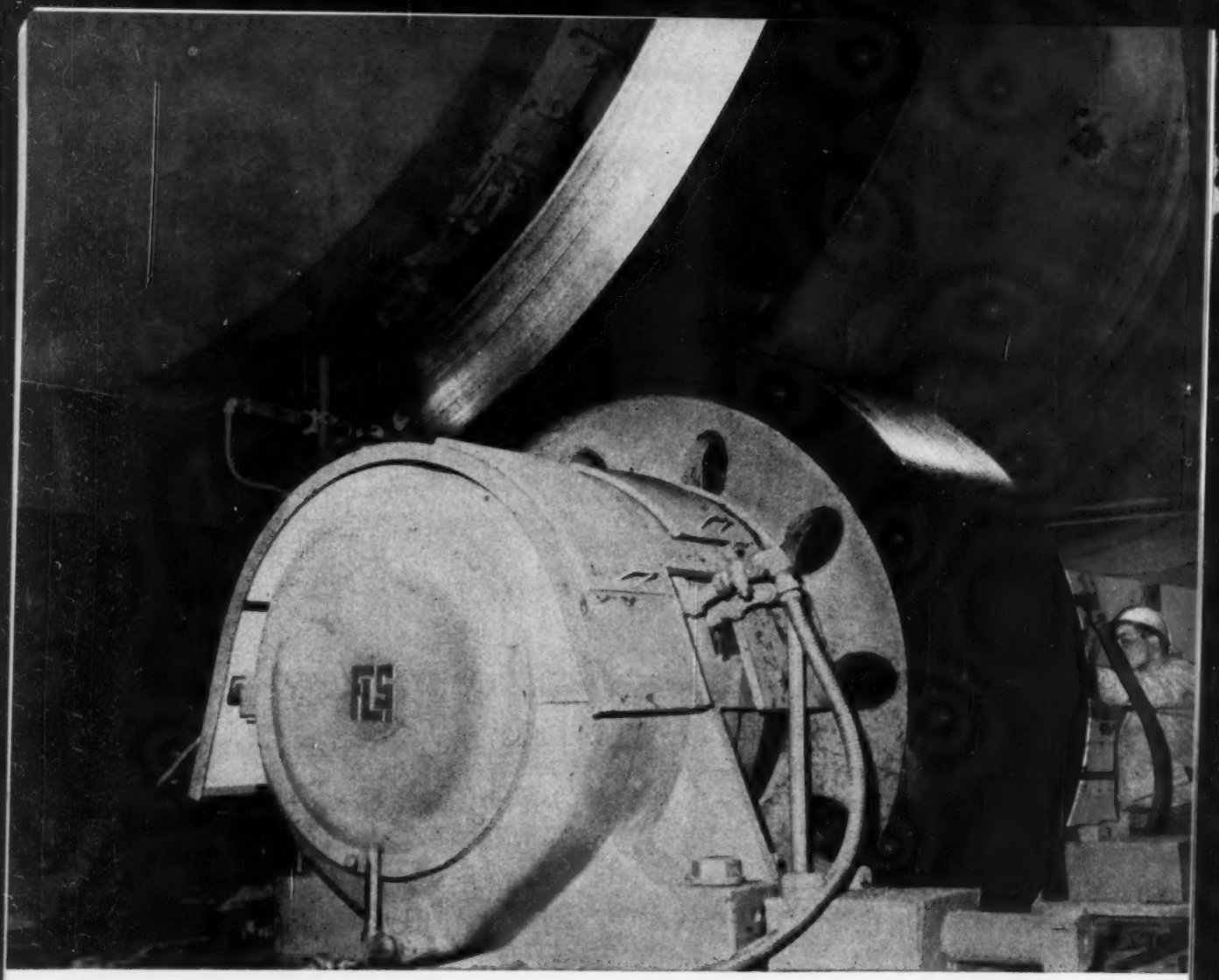
with ROKIDE Ceramic Coatings*

Write for full details on the ROKIDE Coating Process.

NORTON
REFRACTORIES
Crystallizing ideas into products

75 years of . . . **Making better products . . . to make your products better**

NORTON PRODUCTS: Abrasives • Grinding Wheels • Machine Tools • Refractories • Electro-Chemicals — **BEHR-MANNING DIVISION:** Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes



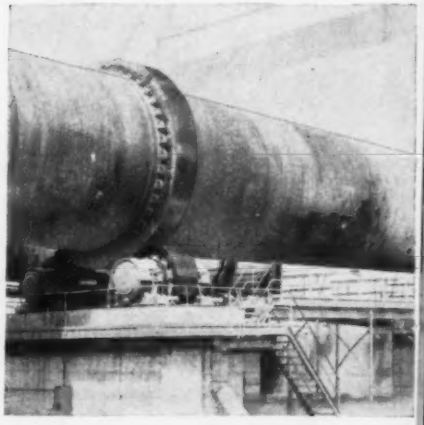
HOW BIG IS A MAN...against *89* tons of cast steel?

These mammoth 89 ton steel tire, kiln supporting and thrust roller assemblies were cast in the foundries of Erie Forge & Steel Corporation. They bear the weight and facilitate the operation of the largest rotary cement kilns in America. The distance between the tire and roller assemblies on each rotary kiln is 100 feet. Cast steel tires are over 20 feet in diameter, weigh 60 tons each. Thrust rollers weigh 6¼ tons each and kiln supporting rollers 22½ tons each.

Each of these two giant kilns produces over 8000 barrels of cement daily with ease in the Dundee Cement Company plant at Dundee, Michigan

By comparative size the man is small—but men made these steel behemoths and men run them. The men of Erie Forge & Steel Corporation welcome the challenge to furnish steel castings and forgings, from pounds to tons, for the diverse machines of industry.

Submit your cast or forged steel component requirements to us with full confidence.

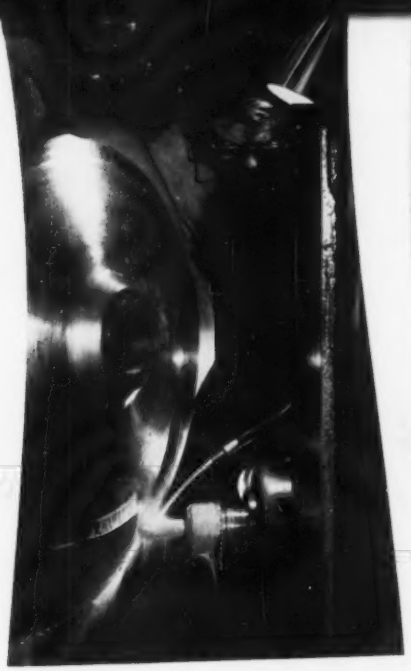


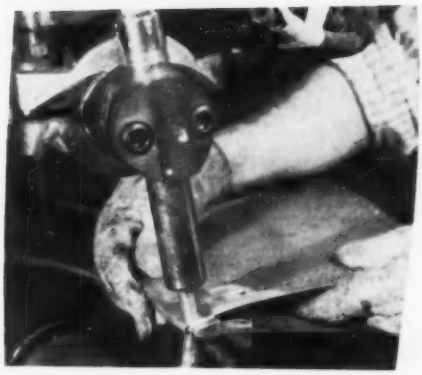
Photographs are by courtesy of F. L. Smidth & Company, designers and builders of "The Largest Rotary Cement Kilns in America."

ERIE FORGE & STEEL CORPORATION

ERIE, PENNSYLVANIA

Circle 1420 on Page 48-B





What Metal Shall I Use?

Today,
more than ever before,
manufacturers are seeking
improved metals
to reduce production costs.
By selecting the
right metal for a job,
metals engineers
can take full advantage
of the economics
of modern fabricating
and processing methods.
The special reports
in this issue are presented
to assist men
in the metalworking industry
in making a technical audit
of their objectives
and to help in evaluating
production procedures
for attaining them.

METAL PROGRESS

Vol. 80, No. 4
October (Metal Show Issue) 1961

M P Special Report To Technical Management in Metalworking

What Steel Shall I Use . . .

for Heat Treated Parts in Automobiles, Trucks and Tractors?

In today's automotive components, parts to be heat treated are made from a wide variety of carbon and low-alloy steels. In general, shafts and springs are quenched and tempered, while parts which must withstand wear (such as gears and piston pins) are usually carburized. Wide use is also made of selective heating processes for hardening. (T21, T3n, J-general; ST)

OVER THE YEARS that cars, trucks, and tractors have been produced, engineers in these industries have gained much experience in selecting and heat treating steels for stress-bearing components. Today, more than ever, they are on the lookout for cost-cutting techniques along with better, more efficient ways to process materials. Their record of accomplishment is worthy of attention by all who are concerned with the application of steels.

Factors in Selection

There seems to be no general rule for choosing any one grade of steel or processing method over another. In fact, it is interesting to note that each major manufacturer of automotive equipment appears to have a different way of handling over-all economies within its own product area. For example, two auto builders (Ford and Chrysler) use the same steels for comparable parts in all of the cars they construct, whether large or small. In contrast, a third (General Motors) often employs a different steel for the comparable component in each of the different cars it makes. Yet, the three manufacturers all operate with efficiency and economy. The varied methods appear to work equally well from a cost standpoint – which is a tribute to the American engineer.

However, though each manufacturer of cars, trucks and tractors has its own idea as to the best grade and heat treatment method for a particular part, all have one basic aim – each wants the desired properties for the least cost. The general approach is summed up by the chief metallurgist for a manufacturer of trucks: "We select the steel capable of producing strength characteristics compatible with the imposed loads required in the application. Once the strength level has been determined, our selection is governed by a fabricated-cost comparison". As an added complication, the heat treating equipment which is available must also be considered. "Oftentimes", he goes on, "we must use a more expensive grade of steel because it can be processed with the existing equipment."

Another chief metallurgist (for a car builder) states, "During the last 30 years, much alloy steel has been replaced with carbon steel with no loss of endurance life or quality. In fact, gains in fatigue life were made in one application – some rear axle shafts now made of induction-hardened carbon steel have higher

Here, Discussing the Metallurgical Problems in Fabricating Track Links, Is Roy Kern, Chief Metallurgist of the Springfield (Ill.) Works, Allis-Chalmers Mfg. Co. Shown with him are Richard Turley (standing), Harold Buckholdt, and Albert Rechner, all of the metallurgical staff

endurance limits than the alloy steel shafts which they replaced."

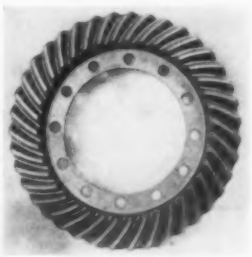
Hardenability Is Important

The two M-P Fact Sheets included in this article list a large variety of carbon steels now being used for many of the stress-bearing parts in cars, trucks and tractors. Furthermore, these steels are generally used in the heat treated condition, being quenched and tempered, carburized, or induction hardened. For such operations the processor generally needs some idea of the steel's hardenability. This complicates things for those who employ carbon steels because there are, as yet, no generally accepted standards for rating their hardenabilities. At this time, however, there is much agitation in this field, and it seems to be getting results. As the Data Sheet shows (p. 96-B), end-quench curves for 1041 and 1045 are now being recommended by the S.A.E..

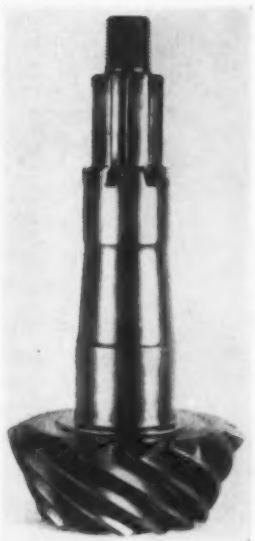
It may come as a surprise to hear that some tractor manufacturers have been purchasing certain grades of carbon steels (1045, 1046 and other medium-carbon varieties) to hardenability specifications for some time. For rating the hardenabilities of carbon steels, they often employ the S-A-C test (sometimes called the Rockwell-inch test) rather than the Jominy test*, so familiar to alloy steel users. Because carbon steels are, in general, shallow-hardening, the S-A-C test generally gives a more sensitive indication of their hardenabilities than does the end-quench test. It will also reveal the effects of segregation because hardness readings are taken across the section.

All in all, the S-A-C test has many backers among the users of carbon steels. An indication

*Actually, some engineers question the end-quench test as an accurate and reproducible method for determining the hardenability of a carbon steel. Because these steels are shallow hardening, the hardness drops off very rapidly within a short distance of the quenched end of the test bar. Therefore, an error of as small as 1/64 of an inch in placement of a hardness impression might make a difference of several points of hardness. This could mean the difference between acceptance and rejection of a heat – and this is a matter of no small concern to either the producer or the user of the steel.

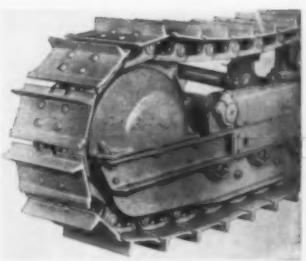


Rear Axle Ring Gear



Automobile Pinion Gear

Crankshaft of 1046 Steel



Track Assembly for Tractor

MP **Fact Sheet**

Steels Used for Heat Treated Parts in Automobiles, Trucks and Tractors

		Crankshaft	Connecting Rods	Piston Pins	Ring and Pinion Gears
Car	A*	1046 (mod.); air cooled to Bhn. 207–255	1139; normalized (1550° F.) and stress relieved (1100° F.), shot-peened	1016 seamless tubing; carburized (1650° F.), WQ & T (350° F.)	4520; carburized (1650° F.), Q & T (300° F.). Case depth: 0.040–0.050 in.
	B	Nodular iron casting; Bhn. 197–285	1041; Q & T to Bhn. 217–255	5015 or 8620 bar; carburized (1700° F.), Q & T (350–375° F.). Case depth: 0.024–0.032 in.	8620; carburized (1700° F.), Q & T (350–375° F.). Case depth: 0.030–0.050 in.
	C	1145; Q & T to Bhn. 235–262	1041; Q & T (1160° F.) to Bhn. 217–269	1019 cold extrusion; carburized (1700° F.), induction hardened and tempered to Rc 57–62. Case depth: 0.064 in. max.	Special grade †; carburized (1675° F.), Q & T (360° F.) to Rc 60 min. Case depth: 0.040–0.050 in.
	D	1046; WQ & T (1100° F.) to Bhn. 228–269	1041; OQ & T (1050° F.) to Bhn. 228–269	1016 seamless tubing; carburized, Q & T to Rc 60 min. Case depth: 0.020–0.030 in.	4027; carburized, Q & T. Case depth: 0.040–0.050 in.
	E	Pearlitic malleable iron casting; AQ & T to Bhn. 217–243	1141; normalized (1550–1575° F.) and air cooled to Bhn. 180–228	1117 bar; carburized, Q (in caustic) & T. Case depth: 0.030–0.040 in.	4520; carburized, OQ & T to Rc 60 min. Case depth: 0.040–0.050 in.
	F	1145; WQ & T to Bhn. 229–269	1141; OQ & T to Bhn. 229–269	1118 bar; carbonitrided (1675° F.), OQ & T (400° F.). Case depth: 0.030–0.040 in.	4118; carburized (1625° F.), cool to 1500° F., OQ & T (350° F.). Case depth: 0.040–0.050 in.
	G	Pearlitic malleable iron casting (ASTM 60003); AQ & T to Bhn. 217–269	1045; Q & T to Bhn. 187–229	1118 bar; carbonitrided (1550° F.), OQ & T (400° F.). Case depth: 0.030–0.040 in.	4118; carburized (1650° F.), OQ & T (300° F.). Case depth: 0.040–0.050 in.
Truck	A	1046; Q & T to Bhn. 197–285‡	4137; Q & T to Bhn. 217–255	5015 or 8620 bar; carburized (1700° F.), Q & T (350–375° F.). Case depth: 0.024–0.032 in.	8620; carburized (1700° F.), Q & T (350–375° F.). Case depth: 0.050–0.070 in.
	B	1046; Q & T to Bhn. 228–269‡	1041; Q & T to Bhn. 228–269	1016 bar; carburized, Q & T to Rc 60 min. Case depth: 0.020–0.030 in.	4422; carburized (1700° F.), Q & T to Rc 60 min. Case depth: 0.040–0.050 in.
	C	1046; Q & T to Bhn. 229–269‡	1141; Q & T to Bhn. 212–241	1016 or 1018 bar; carburized (1700° F.), Q & T to Rc 61–65. Case depth: 0.030–0.040 in.	8620, 94B17, 4817, 94B20, or 4620; carburized (1700° F.), Q & T to Rc 61–65. Case depth: 0.070–0.090 in.
	D	1046; Q & T to Bhn. 248–293 4142; Q & T to Bhn. 285–321	1038; Q & T to Bhn. 217–269 5135; Q & T to Bhn. 223–262	1016; carburized Q & T to Rc 58–65. Case depth: 0.030–0.045 in.	Ring: 8622 and 8625; carburized (1700° F.), marquenched (from 1625° F.), and tempered to Rc 57–63.§ Pinion: 8622 and 4820; carburized (1700° F.), marquenched (from 1525° F. for 4820, from 1625° F. for 8622) and tempered to Rc 57–63.§
Tractor	A	1046; Q & T to Bhn. 248–285‡	1040; Q & T to Bhn. 217–269	1018 or 5120 bar; carburized (1700° F.), reheated, Q & T. Case depth: 0.030–0.040 in.	8822 or 8622; carburized (1700° F.), reheated, Q & T. Case depth: 0.070–0.090 in.
	B	1046; Q & T to Bhn. 229‡	1041; Q & T to Bhn. 302	1018; carburized, reheated, Q & T. Case depth varies.	8822 or 8720; carburized, reheated, Q & T (300° F.). Case depth varies.
	C	1046; Q & T to Bhn. 241–286‡	1041; Q & T to Bhn. 241–286	1019 or 1117 bar; carburized, Q & T to Rc 56 min. Case depth: 0.035–0.045 in.	Ring: 8620; carburized, slow cooled, reheated, Q & T (360° F.) to Rc 60 min. Pinion: 8620; Q & T (360° F.) to Rc 60 min. Case depth: 0.045–0.055 in.
	D	1046; Q & T to Bhn. 248–277‡	1041; Q & T to Bhn. 207–241	8617 or 8620 bar; carburized (1700° F.), slow cooled, reheated to 1550° F., Q & T to Rc 58–63. Case depth: 1/6 of wall thickness.	8620 or 8627; carburized (1700° F.), Q & T (350° F.) to Rc 58–65. Case depth: 1/6 of chordal thickness.

Symbols: Q: quenched; T: tempered; WQ water quenched; OQ: oil quenched; AQ: air quenched.

*Each column, "A", "B", "C", etc., represents a maker of cars, trucks and tractors. Designations refer to AISI-SAE standard grades; unless otherwise specified, part is a forging.

†Analysis: 0.22 to 0.29 C, 0.45 to 0.70 Mn, 0.70 to 1.00 Ni, 0.15 to 0.25 Mo.

Cluster Gears	Suspension System
4620; carburized (1650° F.), Q (from 1550° F.) & T (300° F.). Case depth: 0.040–0.050 in.	Coil springs: 5160 or 9260; Q & T (900° F.) to Bhn. 444–514
Same as ring and pinion gears.	Coil springs: 5160 or 9260; Q & T to Bhn. 444–477. Leaf springs: 5160 or 5147; Q & T to Bhn. 415–461
	Coil springs: 9260; Q & T (775° F.) to Bhn. 461–514, shot-peened
4027; carburized, Q & T. Case depth: 0.040–0.050 in.	Leaf springs: 5155; Q & T (750° F.) to Bhn. 415–461. Torsion bars: 5160H; Q & T (650–700° F.) to Bhn. 477–532
8620; carburized, Q & T	Coil springs: 9260; OQ & T to Bhn. 444-514, shot-peened
4027; carburized (1700° F.), OQ & T (375–400° F.) to Rc 58 min. Case depth: 0.035–0.045 in.	Coil springs: 9260; coil and OQ (from 1650° F.) & T to Bhn. 444-514
4027; carburized (1650° F.), OQ & T (375–400° F.). Case depth: 0.035–0.040 in.	Coil springs: 9260; OQ & T (900° F.) to Bhn. 444-514, shot-peened
8620; carburized (1700° F.), Q & T (350–375° F.). Case depth: 0.040–0.050 in.	Leaf springs: 5160 or 4068; Q & T to Bhn. 444-477
4027; carburized, Q & T to Rc 60 min. Case depth: 0.040–0.050 in.	Leaf spring: 5160; Q & T (750° F.) to Bhn. 444-477
8620; carburized (1700° F.), Q & T to Rc 58–63. Case depth: 0.035–0.045 in.	Leaf springs: 5160; Q & T to Bhn. 401-444
8622; carburized (1700° F.), marquenched (from 1625° F.), and tempered to Rc 57–63. Case depth: 0.040–0.055 in.	Leaf springs: 5160; Q & T to Bhn. 375–445
8620 or 8622; carburized (1700° F.), cooled to 1500° F., Q & T. Case depth: 0.040–0.060 in.	Leaf springs: 50B60 or 51B60 Q & T to Rc 40–45
8822 or 8720; carburized, reheated, Q & T. Case depth varies.	
5140; carbonitrided. Case depth: 0.005–0.011 in.	
8620; carburized, Q & T. Case depth: 0.030–0.040 in.	
Same as ring and pinion gears.	Leaf springs: 50B60 or 5160 to ½ in. thick incl. and 51B60 over ½ in. thick; Q & T to Bhn. 388–444

‡Bearing surfaces are induction hardened after heat treatment.
§Case depth: 8622, 0.031–0.047 in.; 8625, 0.047–0.063 in.; 4820, 0.060–0.075 in.

of the increase in interest in it (and in the hardenabilities of carbon steels) is shown by comparing the amount of space devoted to it in the 1948 and 1961 editions of the A. S. M. Metals Handbook – one column and three pages, respectively.

Different Techniques Are Used

Many interesting techniques are employed by those companies that use carbon steel for heat treated parts. For example, one manufacturer of crawler tractors extensively tests each incoming heat of steel, the idea being to make sure that it is used for those applications in which its properties are best suited. For years, meticulously kept records of tensile, impact, hardenability and cleanliness properties have provided the background of experience which has enabled engineers in the company to determine the best application for every incoming lot of steel, once its properties have been ascertained.

Another tractor maker – it also builds a diversified line of farm equipment – has effected appreciable cost savings by establishing a category of low-manganese plain-carbon steels that have wider carbon and manganese ranges than do the standard grades. Modifications of the common A.I.S.I. steels 1020 up to and including 1045, these grades are used for parts in which mechanical-property and heat treatment requirements are not particularly stringent. An example of such a modified analysis is the one applying to the A.I.S.I.-S.A.E. 1020 grade; the standard grade specifies 0.18 to 0.23% C and 0.30 to 0.60% Mn while the modified grade permits 0.17 to 0.25% C and 0.25 to 0.60% Mn.

Straight Molybdenum Steels

One major car builder makes wide use of the straight molybdenum alloy steels, particularly in carburizing applications such as gears. There are several reasons behind this practice. For one thing, basic economy of the raw material is an important factor, 4023 and 4027 being the most economical of recognized carburizing alloy grades. These alloys also have excellent machining characteristics. Further improvement in machining can be obtained by using 4024 and 4028, both of which are resulfurized grades.

In addition to these advantages, the straight molybdenum steels also provide good hardenability. As an example, 4422, developed for heavy-duty applications, has successfully replaced 8620, 4720 and 4620. Finally, the use of

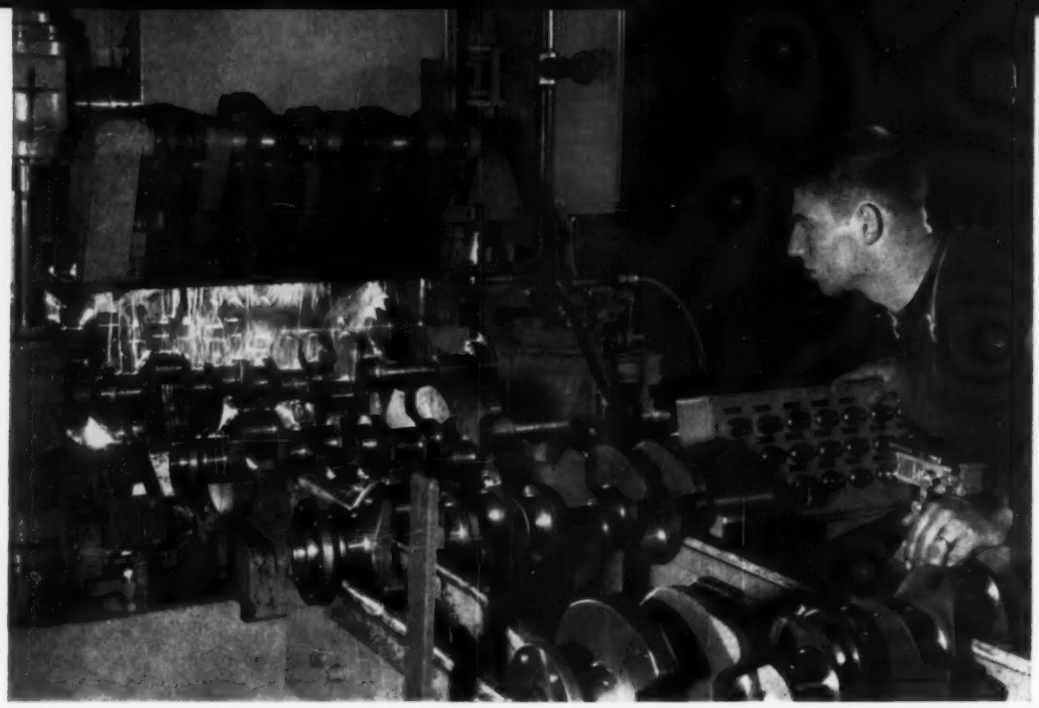


Fig. 1 – As the Final Machining Operation on Automobile Crankshafts, the Bearing Surfaces Are Ground to a High Finish in This Automatic Machine. Crankshafts such as these are made of cast irons or forged steels depending on the manufacturer's preference

a single series of steel allows standardized heat treating cycles.

Complicating the Economics Picture

Sometimes a potentially economical material or method may be considered, only to be discarded in the end because the necessary equipment would cost too much. This is reflected in the variety of materials that are used for automobile crankshafts. The M-P Fact Sheet lists four different choices: pearlitic malleable iron, nodular iron, 1046 and 1145. The two irons are cast, of course, and the steels are forged.

Naturally, the question arises, "Why is there such a variation in materials and in processing when they are all used to make the same type of part which performs essentially the same service?" The answers vary. For example, the fabricating equipment which the company has at its call may be the primary reason for the use of forged crankshafts. This does not mean that the quality of the part is sacrificed because the available equipment precluded the use of castings. The two medium-carbon steels, 1046 and 1145, have the desired combination of hardenability and tensile strength for forged crankshafts in trucks and tractors as well as in autos. In all but two instances, as shown in the Fact Sheet, 1046 is the preferred steel when a forging is used. Because they are generally subjected to more severe stresses in service, most forged crankshafts for trucks and tractors are likely to have an added treatment; after machining, the bearing surfaces are induction hardened for extra wear resistance. Often, these zones are also shot-peened for more fatigue strength.

Many Grades – Few Processes

Actually, although quite a wide variety of carbon and low-alloy steels are employed for making the important structural components in autos, only two principal heat treating processes are in general use. A glance at the Fact Sheet on p. 68 will show that virtually all of the listed parts are either simply quenched and tempered, or carburized and direct quenched. Heat treated parts, such as connecting rods and crankshafts, are often tempered at temperatures high enough to produce a structure that can be easily machined. This reduces production costs because bearing surfaces can then be readily machined to the proper dimensions.

It will be noted that automotive parts which need carburizing, particularly ring, pinion and transmission gears, are made largely of low-alloy steels such as 8620 and 4027. After direct quenching from the carburizing temperature, the only additional treatment generally needed is stress relieving at 300 to 350° F.; this reduces the stresses introduced by quenching to a tolerable level. Gears are generally quenched in oil to minimize distortion. Also, martempering is sometimes employed. Figure 2 illustrates stub shafts (of 5040) for automatic transmissions

which have been martempered and tempered in a mechanized salt bath line to Rockwell C-38 to 40. Since distortion is slight during martempering, the shafts can be finish-machined before treatment.

Steels for Connecting Rods

The Fact Sheet shows that the connecting rods of automobiles and trucks are generally forged of medium-carbon steels. One manufacturer gains added strength by using 4137, a chromium-molybdenum grade, for the heavier connecting rods for trucks. Another uses 1139, a grade with extra sulfur for machinability.

Two popular grades are 1041 and 1141, both of which contain about 1.50% Mn to give them the hardenability needed for full hardening on quenching and tempering. One car builder is able to obtain adequate strength in 1141 connecting rods by normalizing them after forging. This avoids the added expense of more elaborate heat treating. Machining is also abetted because 1141 is a free-machining grade.

Piston Pins – Small But Mighty

Next in order on the Fact Sheet are piston pins. As Fig. 3 shows, these items are hollow steel tubes which hinge the pistons to the connecting rods. When the engine is operating, piston pins are subjected to both wear and fatigue. To gain the needed wear resistance and provide adequate fatigue life, they are usually carburized, quenched, and tempered to about Rockwell C-60.

There are many ways to make serviceable piston pins. For example, some are cold extruded (typical steels: 1016, 1018 and 5015) rather than being machined from bar stock. Reports are that the process is economical because little material (which would otherwise be lost in the form of chips) is wasted. Furthermore, one manufacturer reports that piston pins made from cold-extruded steel have slightly better fatigue resistance.

Another technique employs seamless tubing (usually of 1016). Pins are carburized, quenched in brine and tempered to Rockwell C-60. However, though certain economies are realized through savings in material and machining costs, the practice is said to have one drawback. Variable wall thicknesses in seamless tubing may make it difficult to carburize to a consistent depth. For example, in zones where tube walls are too thin, the pin could carburize through; this could result in a brittle, substandard pin.

Steels for Gears

In connection with selecting steel for gears, it would be well to quote a pertinent passage from the new A.S.M. Metals Handbook (p. 209): "Gears are almost always oil quenched because distortion must be held to the lowest possible level. This means that alloy steels are usually selected – which particular alloy is much debated. The lower-alloy steels, such as 4023, 5120H, 4118, 8620H and 4620, with a carbon range of 0.15 and 0.25%, are in wide use and are generally satisfactory. The first choice usually would be made from the last two steels mentioned, as either should be safe for all ordinary applications. The final choice, based on service experience or dynamometer testing, should be the lowest-cost steel that will do the job. To this list should be added 1024, which, although not classed commercially as an alloy steel, has sufficient manganese to make it oil hardening up to an end-quench correlation point of 3/16 in."

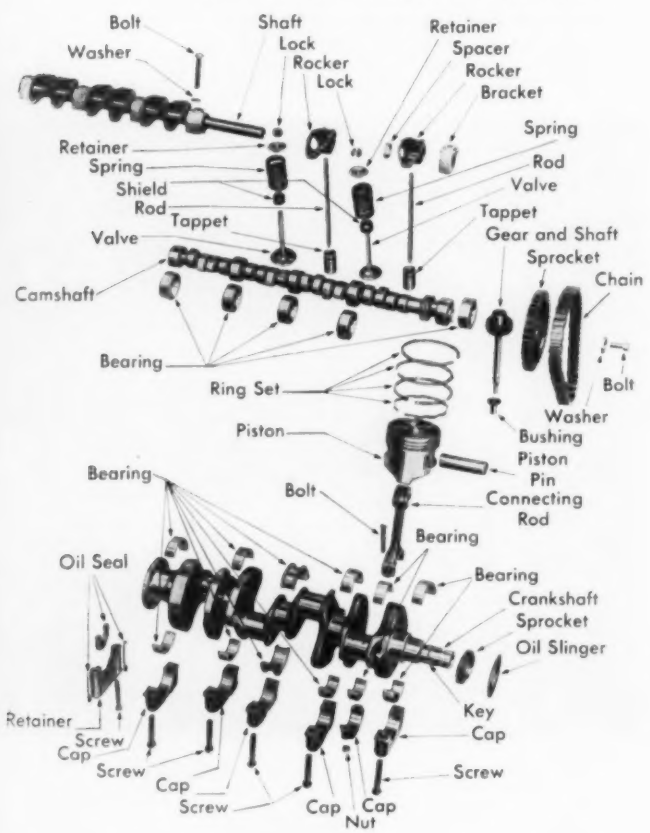
These observations are well supported by the Fact Sheet which shows that ring and pinion gears (for the differential – see Fig. 4) and cluster gears (for the transmission) can be made

Fig. 2 – Stub Shafts (Made of 5040) Are Martempered and Tempered in a Mechanized Ajax Salt Bath Line. Because distortion is limited, these shafts can be finish-machined before hardening

from a variety of steels. Automobile, truck and tractor builders are virtually unanimous in choosing low-alloy steels which contain 0.20 to 0.30% C. (In only one instance is a 0.40% C steel used for a transmission gear. However, it is carbonitrided.) All of the gears made of these steels are carburized to produce the hard, wear-resistant cases that gears must have.

The most popular grade appears to be 8620, particularly for gears in truck and tractor. However, steels such as 4027, 4520, 8622 and 8720 are used, too. Though hardenability and machinability certainly must be considered, the final choice of the gear steel is likely to depend on factors other than the actual properties of the particular steel. One automobile maker states: "Where a number of materials is indicated as optional for a part, the selection is based either upon availability or the hardenability as it relates to section size." In other words, the gear will be made of whichever specified steel is available at the time *provided* it has the needed hardenability.

Fig. 3 – Exploded View of Internal Parts of Automobile Engine Showing Their Interrelation. Note locations of valve springs, crankshaft, connecting rod, and piston pin



Where heavy cases are needed, as in gears for tractor components, case hardenability must also be considered. To quote one chief metallurgist of a tractor plant: "It does no good to carburize to a depth of 0.100 in. and then be able to harden this case (above Rockwell C-50) to a depth of only 0.030 in. because case hardenability is lacking." If desired, this property can be determined quantitatively through the use of end-quench tests of carburized bars.

Tractor Gears Are Re-Austenitized

There is one decided difference between heat treatment methods employed by auto and truck makers and those used by builders of crawler tractors. In general, the former can depend on carburizing, direct quenching and tempering to produce a gear which will stand up in use. However, tractor makers, because of somewhat higher service demand on their products, usually find it necessary to re-austenitize gears after carburizing and cooling them. Then, the quenching and tempering operations that follow will produce a tough, strong core and a hard, wear-resistant case which also has excellent fatigue life because of compressive stresses in the surface zone.

Also, the cases on tractor gears are generally heavier than they are on automobile gears; deeper carburized cases are needed because of the greater wear and high stresses that tractor gears must withstand. One manufacturer designs to about 50,000-psi. bending stresses for suitable life. This company's engineers also report that a suitable rule for case depths is "1/6 of the cross section to provide a part that is 1/3 case, 2/3 core".

The desire of automobile builders to apply direct quenching can result in apparently complex treatments. For example, the following procedure is often employed for manufacturing ring and pinion gears. After being forged, gear blanks are cycle-annealed to produce a machinable structure. Then the teeth are cut, the gears are carburized, furnace cooled to 1500° F., quenched in oil, and tempered to a Rockwell C-60 minimum. As a final step on the pinion gear, the threaded end is tempered to C-40.

Valve Springs Are Important

The primary property needed by a valve spring is fatigue strength to withstand the millions of flexures it will receive during its service life. For this application, builders of automobiles use springs made of carbon steel (the

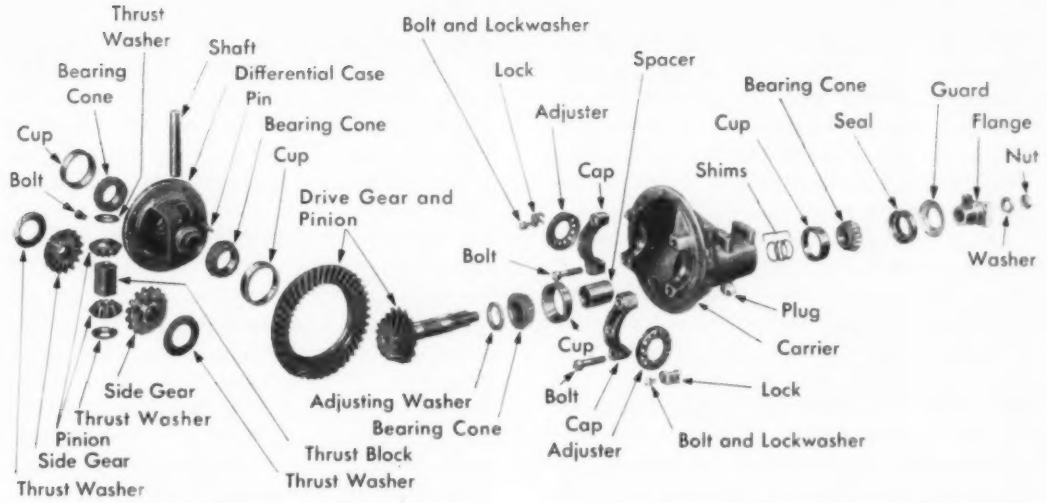


Fig. 4 — Exploded View of Rear Axle Assembly of Automobile. Note location of drive gear and pinion, the main stress bearing parts in this assembly. Several types of low-alloy steel are used for these parts

carbon varies between 0.60 and 0.75%) which are either hardened and tempered, or patented and cold drawn at tensile strengths between 210,000 and 250,000 psi., depending on the wire diameter.

As a general rule, the materials engineers will specify "Valve Spring Quality" wire for this application. When covered by a commonly used specification, A.S.T.M. Designation A 230, such wire must have (aside from the above properties) a minimum reduction in area of 45% and must "be free from imperfections such as seams, pits, die marks, scratches, and other defects tending to impair the fatigue value of the springs". To increase their fatigue life, these springs are usually shot-peened after heat treatment to prestress the surface in compression.

Suspension Systems Vary in Complexity

Automobile suspension systems generally employ leaf and coil springs. (Torsion bars are also employed.) Though a wide variety of steels is used for these parts, the auto builders seem to be unanimous in choosing alloy grades, 5160 being the most widely applied. As to which of these steels is best from a cost and engineering standpoint, there is no one answer.

Taking 5160 and 9260, for instance, the former is less expensive, but smaller volumes of the latter are needed for comparable springs. In other words, a spring, properly designed to be made of 9260, must be longer and larger in diameter if it is made from 5160 and is to have the same fatigue strength and "settle" properties as the 9260 spring. Therefore, in the long run, 5160 may be the more expensive grade if the extra material needed to achieve the required properties overrides the difference in base price.

Alloy steels are favored (over carbon steels) for leaf and coil springs because of their hardenability. Springs should be hardened uniformly across the section, and these sections are usually too large for the hardenabilities of carbon steels. Also, the same heat which is used for hardening is used for coiling. (The spring is coiled while hot, then quenched.) The sluggishness of alloy steels generally insures that no transformation has occurred during the coiling operation. Alloy steels, since they can be purchased to hardenability specifications, also are apt to be more uniform in their response to heat treatment from lot to lot than the corresponding carbon steels.

Alloy spring steels are invariably hardened and tempered to a spring hardness (between Bhn. 401 and 514). As is the situation for valve springs, the springs for the suspension system are shot-peened for added fatigue strength.

In general, tractors do not have suspension systems as do autos and trucks. However, most large crawler tractors have heavy leaf springs and a massive coil spring (usually termed a "recoil" spring) which keeps the track tight and takes up any shocks that might be encountered in service. These coil springs, which must meet rigid standards with regard to mechanical properties and surface quality, are heat treated to spring hardnesses, Rockwell C-40 to 45. Grades such as 1080, 1096, 8660 and 4160 give satisfactory service.

Cars, trucks and crawler tractors all have different setups for steering. For example, though cars and trucks are steered through similar types of steering gears, cars do not have solid front axles as do most trucks. Instead, each front wheel in a car is independently linked to the frame through short swing arms and ball studs. In trucks, kingpins connect the steering knuckles to the front axles.

As in the selection of steels for the other heat treated parts in automotive equipment, a variety of steels is used for steering knuckles and king pins. The former, for example, are forged of 1340, 1345, 1046, 8640 and 8645. Normally, they are austenitized, quenched and tempered to hardnesses ranging from Bhn. 217 to 341, depending upon the stresses that must be withstood in service.

One car manufacturer reports that 1340 had been used for over 20 years, but as the car weight increased, the size of the steering knuckle increased. Finally, the hardenability had to be raised, so the manufacturer found it necessary to go to 1345, a steel with the extra hardening potential that was needed for the heavier section, but which cost the same as the other. Another car builder selectively hardens the bearing fillet (by induction) because that zone of the steering knuckle needs to withstand the highest stresses in service.

The kingpins used on trucks are made from any of a group of steels including 8622, 8617, 4620, 3120, 1050, 4615 and 8615. Those made of 1050 are induction hardened (Rockwell C-60 min.). Kingpins made of the lower-carbon steels, however, are carburized, quenched and tempered to about Rockwell C-60.

Some variations in treatment exist. One truck builder, for instance, employs the martempering process; its 8622 kingpins are carburized,

MP Fact Sheet **Heat Treated Parts for Track Assembly of Crawler Tractors**

Track Parts	A*	B	C
Shoe	1050 rolled section; Q & T to Bhn. 250; grouser: hardened and tempered to Rc 43–50	1040 rolled section; Q & T to Bhn. 229–302; grouser: flame hardened and tempered to Bhn. 341–429	1045; Q & T to Rc 32–35
Link	1041, 1043 or 1046; Q & T to Rc 25–32; rail surface: induction hardened to Rc 50–58	1042; Q & T to Bhn. 229–302; rail surface: induction hardened to Rc 55 min.	1045; Q & T to Rc 40–45
Pin	1045; induction hardened to Rc 60–66	1055; induction hardened to Rc 55 min.	1050; induction hardened to Rc 60 min. at surface and Rc 40 at 1/8-in. depth
Bushing	1018 or 1026; carburized and surface quenched. Timing is such that case is tempered to Rc 60–66 by remaining heat. Case depth: 0.070–0.090 in.	1019 seamless tubing; carburized, Q & T to Rc 56 min. Case depth: 0.063–0.073 in.	1018 seamless tubing; carburized, Q & T to Rc 60 min. Case depths: 0.065–0.080 in. and 0.095–0.110 in.
Sprocket	Cast steel (0.40–0.50% C); die quenched or flame hardened; teeth: Rc 45–55	Cast steel (0.40–0.50% C); teeth: flame hardened to Rc 45–55 after tempering	Cast steel (0.40% C, 0.70% Cr); Q & T to Bhn. 241–302; teeth: induction hardened to Rc 50–55
Idler	Cast steel (0.40–0.50% C); rim: induction hardened to Rc 45–52	Cast steel (0.40–0.50% C); rim: flame hardened to Rc 45–55 after tempering	Cast steel (0.40% C); rim: induction hardened to Rc 50 min. on surface, Rc 40 min. at 1/8 in. depth
Track rollers	1043, 1045 or 1049; rim: either Q & T or induction hardened to Rc 52–60	1040; rim: induction hardened to Rc 47 min. Case depth: 3/16 in.	1045; Q & T to Rc 52 min. on surface, Rc 45 min. at 1/8 in. depth. Quenching is timed so the residual heat tempers the part
Support rollers	Chilled alloy cast iron; rim: Rc 42–60 or 1049; rim: Rc 52–60	Gray iron casting; Bhn. 197–241	1045; induction heated and quenched to harden rim to Rc 55 min. at surface, Rc 40 min. at 1/8 in. depth. Tempered by control of residual heat

Symbols: Q & T: quenched and tempered.

* Three leading manufacturers of crawler tractors are represented in the "A", "B" and "C" columns.

quenched, and tempered to Rockwell C-57 to 63 (case depth: 0.026 to 0.048 in.). Another manufacturer, one that generally uses 4615 forgings, carburizes its kingpins, then after dropping the temperature to about 1550° F., quenches in oil and tempers at 325° F.

Steering the Crawler Tractor

In a sense, the crawler tractor is in a class by itself as far as the motive method and setup for steering are concerned. Running on endless tracks, consisting of steel plates strung together, it is steered by stopping the appropriate track (right or left) while the other continues to move.

In assembling the track, shoes are bolted to links, and the links, in turn, are hinged to each other by pins and bushings. When installed and in operation, the track is actuated by the "sprocket" and is supported by the "idler" and "rollers". This track assembly and its auxiliary equipment are a critical problem in steel application and treatment. Since all of these parts are in the open air, they are subjected to all sorts and conditions of weather and abrasive wear as well as being under extreme stresses most of the time.

The M-P Fact Sheet on p. 74, which lists the steels and heat treating procedures used for components of track assemblies, shows that extensive use is made of the medium-carbon grades, and that induction hardening is widely employed. Furthermore, some of the tractor makers report that they are able to forego tempering after quenching. Instead, they apply a timed quench (on such items as sprockets and idlers). The outer surface is quenched, but quenching is stopped while the core is still hot enough to temper the hardened surface.

Such operations, of course, require very close timing and good control of material with reference to hardenability variations. For this reason, some manufacturers prefer to use alloy steels because it is simpler and less costly to employ conventional quenching and tempering treatments.

Tractor builders place much reliance on the medium-carbon grades, 1040 to 1050, for making track shoes, links, and pins. For economy in manufacture, track shoes are made from hot-rolled stock, the cross sections of which are rolled to the contour of the longitudinal sections through the shoes. After being cut to the required lengths, shoes are generally austenitized, quenched and tempered to a hardness which will give a combination of wear resistance and toughness. (One manufacturer uses a hardness range of Rockwell C-32 to 35 for its 1045 shoes). The grousers (the sharp ridges on the shoes which dig into the ground when the tractor is operating) are generally flame or induction hardened to Rockwell C-45 to 50 because they are subjected to a greater amount of wear than the rest of the shoe.

The information contained in this article and the Fact Sheets was gathered through the cooperation of engineers associated with the companies listed below. Without their assistance, very little could have been accomplished by the editors. We thank them most gratefully.
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General Motors Corp., Detroit
International Harvester Co., Chicago, Ill.

Induction Tempering

One manufacturer induction tempers track shoes after quenching them. To treat these shoes, which are made of 1050, induction heating is applied from the side of the shoe which contacts the links. Timing is such that the other side does not reach the same temperature. By this means, the other side (which contacts the ground) will have a higher hardness for greater wear and abrasion resistance. After this treatment, the grouser is induction hardened and quenched to Rockwell C-43 to 50 for extra wear resistance.

Links and pins also undergo extremes in abrasive wear and temperature. As with track shoes, much use is made of induction hardening techniques for treating these critical items. One manufacturer uses 1335, a high-manganese steel, for links. The extra manganese (1.45 to 2.05%) gives the steel a hardenability which is equivalent to that of medium-carbon grades with higher carbon levels.

Track bushings, unlike shoes, links, and pins, are case hardened because they receive added wear from contact with the sprocket teeth. As the M-P Fact Sheet shows, most tractor builders use 1018 (one uses seamless tubing; another cold extrudes its bushings). Bushings are hardened by carburizing, quenching and tempering. In one instance, a tempering operation is avoided by a timed quench (in brine). The

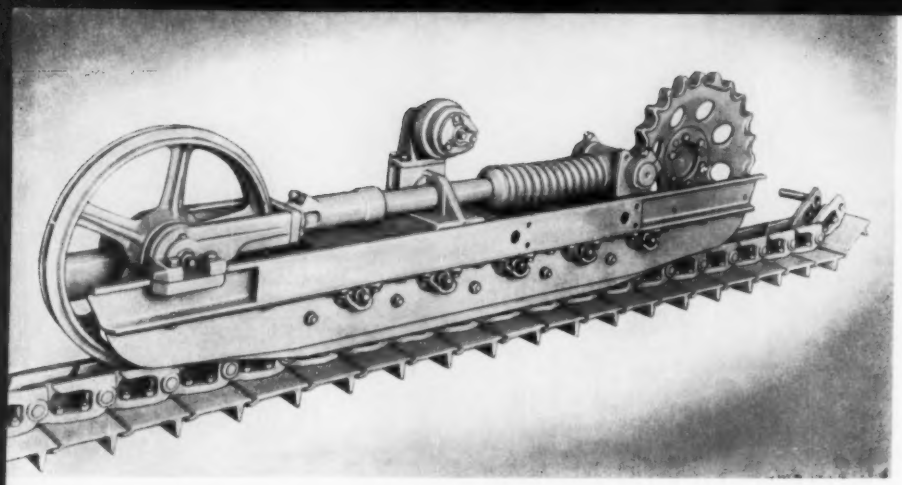


Fig. 5 – Track Assembly of Crawler Tractor Partly Disassembled to Show Idler (Left), Support Roller, Recoil Spring, and Sprocket. At the bottom, track pins and bushings connect the track links to which are attached the track shoes

bushing is pulled from the quenchant while still fairly warm, and the remaining heat tempers the case.

Sprockets and idlers are generally made from cast steel (0.40 to 0.50% C) although one producer uses welded parts with rims of 1035. Both of these components are hardened on the outside surfaces for wear resistance. In a sense, sprockets can be considered as large gears. Thus, like such gears, they can be press-quenched to harden the teeth. Sprocket teeth are also hardened by flame or induction-hardening techniques as are the rims of idlers. These sprocket and idler hardening operations often employ timed quenches that allow the remaining heat to temper the quenched surfaces. If this is done with the proper timing, added heating for tempering is unnecessary.

The bottom rollers, which guide and support the track between the sprocket and idler, are made of steels containing 0.35 to 0.45% C, depending upon the manufacturer. Since their rims must withstand constant wear from the track, they are heated and quenched on the outside surfaces in much the same manner as idlers.

Tractor manufacturers also make good use of carbon steels for highly stressed shafts and axles. When such parts have regular shapes and relatively constant cross sections, they can often be made of medium-carbon steels (such as 1035, 1040 or 1045) and induction hardened. In fact, one tractor builder "shell" hardens irregularly shaped main axles (of 1040 steel) by furnace heating and "scan" quenching for fatigue resistance.

What the Future Holds

There is a constant trend toward increased engine power, particularly in the tractor and truck fields. In general, engineers achieve increased power not by designing larger engines (this means using greater amounts of steel and other materials), but by such measures as raising engine speeds and adding superchargers. Thus, stronger, more heat-resistant materials to withstand the increasing stresses and temperatures are always being demanded.

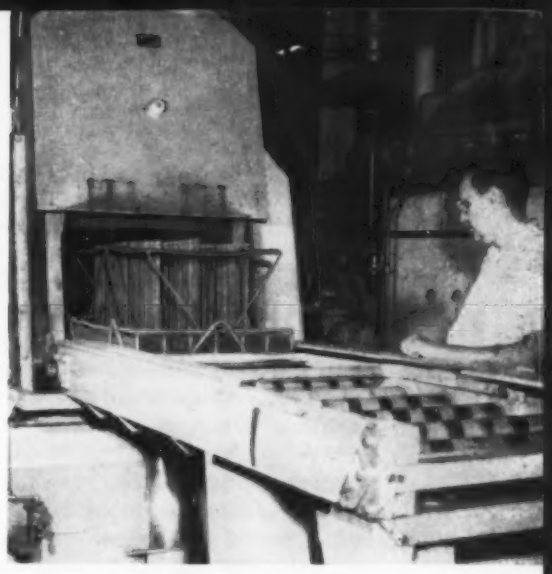
Cleanliness is one property which will have to receive more attention from steelmakers, according to one tractor manufacturer. This may mean increased interest in vacuum-degassed steel, a material which has been used chiefly for heavy forgings (die blocks and turbine rotors, for example) up to now. Another trend, according to a chief engineer for a car builder, is that "The foundry people are making a strong bid to take business away from the forge shops. We should not be too surprised soon to find connecting rods and similar parts made from ductile cast iron."

Another metallurgist, concerned with trucks, believes that much more needs to be known about the materials now available in order to use them effectively. He states: "It is expected that we will gain a more thorough understanding of the strength characteristics of steel, and, along with this (through experimental stress analysis), a more finite determination of the types and magnitudes of strengths required for a given application." With this combined knowledge, he feels, engineers will have a more rational approach to the selection of materials than the cut-and-try method used so often in the past. In short, he expects a "much more positive combining of engineering mechanics and metallurgical engineering."

One thing is certain. Competition will continue to be a part of the car, truck and tractor manufacturing scene. As such, it will always have to be considered by the engineers who work in these fields. They will be ever alert in applying new processes or materials which will help them to manufacture a more efficient, yet more economical, product.

What Steel Shall I Use . . .

for Heat Treated Parts in Business Machines and Home Appliances?



Many Business Machine Parts Are Case Hardened for Wear Resistance

Though the manufacturers of these two types of equipment make many different types of items, heat treatment processes are usually restricted to case hardening methods because wear resistance is the chief property desired. Much use is made of free-machining steels and powder metal parts. (J-general, T10c, X14, 17-57)

Precision Gears of Leaded Steel

As one might expect, makers of business machines and home appliances use heat treated steels in stress-bearing parts as do automotive manufacturers. Although cost is just as important a factor as it is to the automakers, the pattern of usage is somewhat different because these two industries make such a wide variety of products. For example, the makers of business machines produce most types of office equipment from adding machines and typewriters to elaborate data processing systems requiring groups of specialized units.

Likewise, makers of home equipment construct and sell items ranging from small, simply built can openers to large and complicated pieces of home laundry machinery. Under such circumstances, it is difficult to outline, or even discern, a simple pattern of materials selection and processing for individual parts. However, a consideration of the methods followed by individual manufacturers will present some worth-while ideas.

Fluted Shaft With Case Hardness of R,62

Washing Machine Gears of 1213, Carbonitrided

Carbonitrided Part for Accounting Machine

Home Appliances – Few Critical Parts

With regard to heat treated steels in home appliances, the type of service that most of the components perform is such that there is little reason to specify heat treated parts or alloy steels. In fact, about the only home appliances that have moving parts are laundry equipment (washers and driers), dishwashers, waste disposers, and cooling units (air conditioners, refrigerators, dehumidifiers, and the like). Even these items have little in the way of heat treated parts. For example, the Maytag Co., one of the major producers of home laundry equipment, reports that it basically employs only three types of steels which are heat treated, A.I.S.I. 1117, 1213 and 1141. Furthermore, the heat treat-

ments are generally case-hardening processes applied when good wear resistance is needed. The first two steels are usually carbonitrided, and 1141 is induction hardened. In only one instance does Maytag use an alloy steel; its most stringent application, a drive sleeve for a wringer-type washing machine, calls for an A.I.S.I. 8620 (containing lead for machinability). This part is carbonitrided to about 0.010 in. for resistance to fatigue and wear.

Maytag also uses Type 416 stainless steel where corrosion resistance is important, hardening it in an endothermic atmosphere. Various types of cast irons (gray, ductile, and malleable, for example) are used for gears; they are normalized for wear resistance, machinability, and dimensional stability. Self-tapping screws are made from A.I.S.I. 1019, being carbonitrided for strength and cutting properties.

Cooling equipment usually contains small compressers to force the refrigerant through the cooling coils of the unit. Although these items are expected to give quiet service for years on end, application problems are not particularly stringent. This is largely because compressers are hermetically sealed so that the moving parts – piston, connecting rod, crankshaft and valves – operate in an atmosphere of oil and refrigerant. Air and moisture are reduced to very low levels. Thus, corrosion of internal parts is not a problem, and parts can be made of materials which are not ordinarily mated to each other because of such difficulties.

For example, one company makes the crankshaft of pearlitic malleable iron, the piston and connecting rod of aluminum, the piston pin of low-carbon seamless tubing and the valves of a high-carbon spring steel. In the compresser, only the piston pin and the valves – flat springs which open and close to let refrigerant in and out of the compresser cylinder – are heat treated. The piston pin is carburized for wear resistance, and the valves are made of sheet steel quenched and tempered to a tensile strength of 275,000 to 300,000 psi., depending upon the thickness.

Business Machines Are Complicated

The situation is somewhat different for business machines. Since most of them are quite complicated, yet are expected to give years of continuous, trouble-free service, manufacturers make good use of heat treating practices. In particular, case-hardening processes such as carburizing and carbonitriding are widely used.

Parts used in business machines require extreme accuracy, and usually operate at high stresses. A quotation from a paper on "The Control of Carbonitriding", by John B. Given (staff metallurgist at I.B.M.) presented at a Rochester Chapter meeting will give an idea of the problems involved:

"The mechanical components of our tabulators and computers consist of mechanisms for feeding cards or tapes, sensing devices, counters, analyzer units, and high-speed printing mechanisms. All of these must operate at high speeds and some with little or no lubrication. Small contact surfaces with extremely high unit loads require optimum surface hardness. Extremely close tolerances for flatness and dimensions must be maintained. Many parts are made from strip steel only 0.040 in. thick. The major part of our heat treating processing thus consists of light case work.

"Steels used for these applications are A.I.S.I. B 1113, C 1117, C 1010, C 1018, 8617 and 8620. Case depth specifications range from 0.002 to 0.003 in., and up to 0.015 to 0.030 in. Case depth above 0.010 in. comprises only about 10% of the total."

Business machine makers use carburizing and carbonitriding practices which differ from those employed in the auto industry. As Mr. Given stated, dimensional accuracy and wear resistance are needed in gears and other parts which are usually quite thin; thus they aim for much thinner cases than do the automotive people. Because of this, carbonitriding between 1500 and 1550° F. is a favored treatment. Not only can cases be controlled at depths as low as 0.005 in., but cores are also tough when heated and quenched from these temperatures. Thus, parts can be direct quenched after hardening.

As would be expected, it is not a simple matter to produce thin cases with consistent case depths. At I.B.M., a modified gas carburizing treatment is employed for parts which are to be selectively hardened. Ammonia is added only for the first 40 min. of the carburizing cycle (total cycle is 1 hr. at 1550° F.). The as-carburized case hardnesses – ranging around Rockwell C-30 – leave the parts in condition for further machining operations.

Types of Steels Used

Carbon and low-alloy carburizing grades are the most popular steels for business machines. Both I.B.M. and National Cash Register Co. use large amounts of A.I.S.I. 1010, 1111, 1112, 1113, 1117, 8617 and 8620. At I.B.M., A.I.S.I. 1010 and 1113 are used for parts requiring cases (car-

bonitrided) between 0.003 and 0.005 in.; A.I.S.I. 1117 is used if the cases are to be somewhat heavier (0.006 in.). According to J. S. Meyer of I.B.M., such "heavy" cases are used on shafts in which fatigue failures might be expected. "Shafts such as this often perform 250,000 operations in one day!", he adds. For highly stressed parts, 8617 and 8620 are used, the former grade being employed for strip parts (lower carbon gives better formability). Some gears which receive heavy service are made of A.I.S.I. 4150. After heat treating to about Rockwell C-30, the teeth are machined and flame hardened to a Rockwell C-55 minimum.

Heat treated castings are also used. For instance, I.B.M. employs pearlitic ductile iron for some parts on which sections are selectively flame hardened. It also uses investment castings of A.I.S.I. 8620; these are normalized and case hardened by carburizing or carbonitriding.

Business machine manufacturers also make wide use of powder metallurgy techniques for the sake of dimensional accuracy. Furthermore, parts made of high-density iron sinterings (above 7.4 g. per cu.cm.) are often carburized or carbonitrided for strength and wear resistance. Through powder metallurgy, small and complex parts can be made with few operations. As a consequence, though the original cost of the iron powder is rather high, savings are achieved by the smaller amount of handling that is needed for fabrication. Analyses comparable to carbon steel grades are occasionally made by carburizing iron powder parts throughout the section thicknesses.

In typewriters the parts which receive the most wear are the type bars. Here, again, familiar grades are employed. At N.C.R., for instance, type bars (used on the typing mechanisms of some business machines) are made of A.I.S.I. 1022. The bars are formed, case hardened by cyaniding and tempered. As for the type blocks, they are made of A.I.S.I. 1010, cyanided for wear resistance.

At Royal McBee, a different method is used for type bars. As reported by Donald Flannery in Metal Progress (November 1959, p. 91), that company employs A.I.S.I. 1055 strip. After being formed to shape, the bars are austenitized at 1520° F., and quenched to 710° F. where they are held until transformation to bainite is complete. The type ends are then selectively tempered at 860° F. All austenitizing and tempering operations are carried out in salt baths.

The Metallurgist's Role in Selecting Materials for Business Machines

*By D. C. WILLIAMS**

When choosing the correct alloy for a stress-bearing part in a business machine, the final decision is generally made through the combined effort of the design engineer and the metallurgist. As described here, this procedure was followed in determining the material and heat treatment for three critical parts of a typical business machine. (X14, J-general, 1-54; TS)

IN THE MANUFACTURING FIELD, the metallurgist is usually called upon to work with the design engineer in selecting materials for machine parts. This is particularly true in the business machine field. Since space and weight requirements are continually tightening, the design engineer, by necessity, generally works on machines with closely packed moving parts

*Chief Metallurgist, Addressograph-Multigraph Corp., Cleveland.

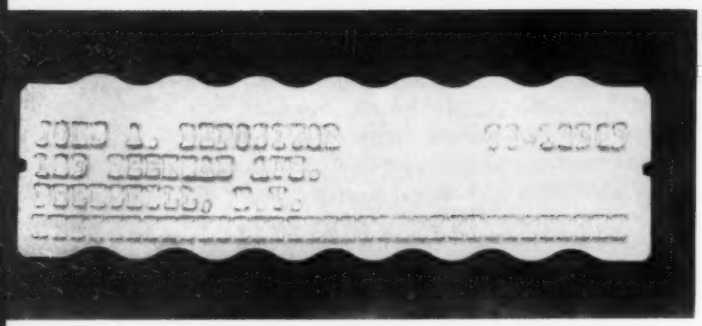
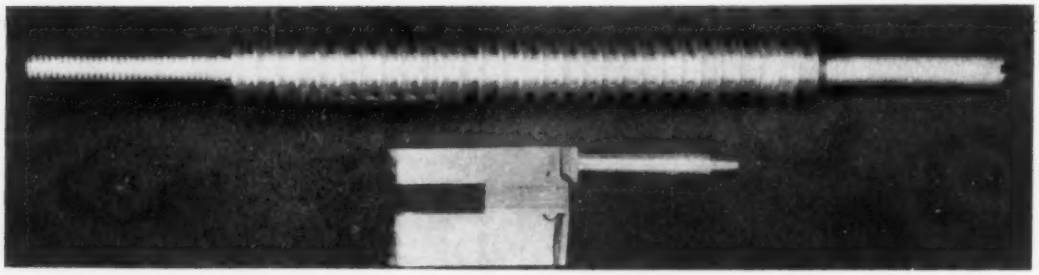


Fig. 1 – This Apparently Simple Plate Is Made by the Graphotype, a Complex Machine Built of Many Parts

Fig. 2 – Rack and Pawl (Below) for the Graphotype. These two parts must have good wear, fatigue and impact resistance to undergo heavy service for long periods. The rack is made of A.I.S.I. 1117, the pawl, from a shock-resisting tool steel – S3 modified with additional chromium



which must meet heavy service demands for long periods of time. Also demanded are low material and manufacturing costs, higher operating speeds, reduced wear, greater impact properties, better machinability, and uniform results in heat treating. All these desires, when put together, produce many different problems, each of which requires careful study by the metallurgist.

As an illustration, let us consider the selection of materials for critical parts in the "Graphotype", a machine that embosses metal and plastic plates (Fig. 1) for addressing and data recording equipment. For example, the rack and pawl (Fig. 2) which space the characters on the plates introduce several difficult problems in design, metals selection and production. First, as the pawl moves, only its corners contact the rack. Thus, the wear and impact on these corners – and the rack teeth as well – is considerable. Furthermore, there is much wear on the face of the pawl as it slides against the rack. In some instances, the rack may travel its full length so that the pawl drops into its last tooth. Since there is high spring pressure in this action, both the top sections of the pawl tooth and the rack tooth undergo much impact; this produces a shearing action which may cause either the rack or the pawl tooth to fail.

Tool Steel Used for Pawl

After much testing, we selected (for the pawl) a shock-resistant tool steel, A.I.S.I. S3 modified with additional chromium (nominal analysis: 0.50 C, 1.00 Cr, and 1.00 W). As for heat treatment (to produce wear resistance, core hardness and toughness), the part was treated at 1650° F. for 30 min. in an endothermic atmosphere, quenched for 10 min. at 240° F., and double tempered. Each tempering cycle was 2 hr. to a final hardness, at the surface, of Rockwell A-78 to 79.

The rack is both difficult to machine and to hold at close dimensional tolerances through heat treatment. For this part, a free-machining steel, A.I.S.I. 1117, was chosen. This grade machines easily, develops a uniform case when carburized, and has good dimensional stability, wear resistance and toughness. To heat treat this part, we carburize for 1 hr. at 1600° F. in an endothermic atmosphere and cool in a controlled atmosphere. After the parts are reheated at 1475° F. in an endothermic atmosphere, they are oil quenched for 10 min. at 240° F., and tempered at 450° F. to a final hardness of Rockwell 30N-70 to 74. In both the rack and pawl, case depth is closely controlled, parts being taken from each furnace

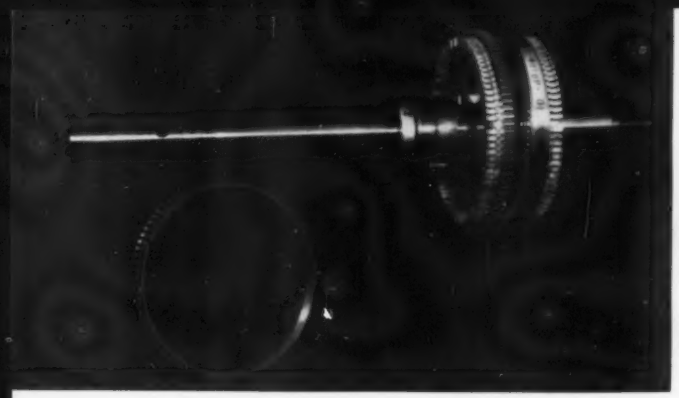


Fig. 3 – Graphotype Die Head With Register Ring. The register ring, which is shown separately, offers problems in hardening and machining, particularly because the teeth are cut after the part is hardened to Rockwell C-46 to 50. This part is made of A.I.S.I. 4150 with added sulfur for improved machinability

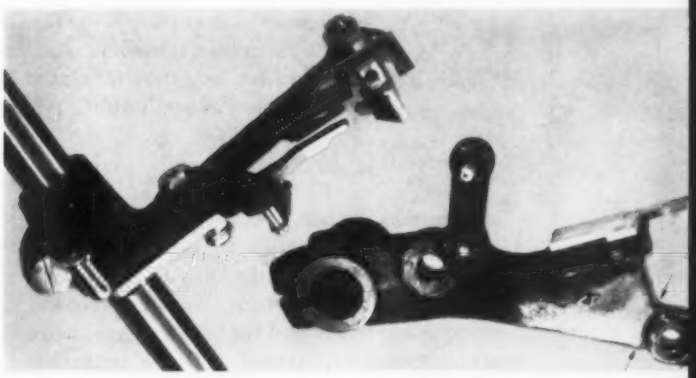


Fig. 4 – Stop-Arm Forging and Assembly for Graphotype. Arrows indicate zone which undergoes much stress from clamping screw through split end; this zone is polished to eliminate pits and scratches which might otherwise act as stress raisers. Made of A.I.S.I. 6145, the part is heat treated to Rockwell C-33 to 37

load and checked before the load is released for production.

Free-Machining Alloy Steel Selected

The register ring shown in Fig. 3 also presented a problem in materials selection. When we were called in to investigate, the tool steel being used for the part was giving trouble. Machinability was poor and nonuniform, particularly during finish machining. (The teeth are given the finish cut at Rockwell C-46 to 50 after the ring has been attached to the die head.) Furthermore, the tool steel we were using had borderline hardenability – it was difficult to obtain full hardness and retain roundness and flatness without press quenching.

After analyzing the design and production factors, we finally selected a resulfurized A.I.S.I. 4150 with a 50% spheroidized structure. Machinability of the blank (measured by tool life) increased 100%, hardenability was satisfactory, and warping was practically nil. Furthermore, machinability at Rockwell C-46 to 50 increased 200%. For heat treating, the parts are heated at 1550° F. for 30 min. in an endothermic atmosphere, oil quenched for 10 min. at 240° F., and tempered for 2 hr. at 850° F. The new material also cost but half as much as the steel it replaced.

Another instance in which materials selection is important concerns the forging shown in Fig. 4. This stop arm is subjected to considerable impact during operation. The end with the small hole is under tension at the zone indicated by the arrows. (At that end a holding screw through the split end clamps an eccentric.) For this part, we use A.I.S.I. 6145.

As received, the forging is carbon-corrected (to replace the carbon lost from the surface in heating); this treatment also aids in producing a uniformly annealed structure for machining. After machining, the part is heated in a controlled atmosphere for 15 min. at 1600° F. and oil quenched 10 min. at 240° F. Tempering for 5 hr. at 1050° F. to Rockwell C-33 to 37 completes the treatment. As a final operation, the critical area indicated by the arrows is polished to remove any stress raisers which might induce premature fatigue failure.

Such problems as these are a daily affair to the metallurgist concerned with materials selection. Each new design brings new difficulties, which must be resolved before production on a volume basis is practical. As a consequence, the designer and the metallurgist generally work together; their combined talent enables them to choose the correct material for virtually any application and to keep costs in line.

What Steel Shall I Use . . .

for Nitrided Parts?

By WILSON LEEMING*

As a means of imparting wear resistance at elevated temperatures, nitriding is receiving much consideration. For example, H11 gears for long-time service at 500° F. are now being nitrided, and other similar applications are being studied. (J28k, Q9n; CN, AY)

IN THIS "SPACE AGE", as it is called, the nitriding process is receiving more and more attention from manufacturers. For example, nitrided steels are now being used in precision bearing components and for power gears in aircraft accessory equipment. Where operating loads and temperatures are high, nitrided steels deserve attention because of their ability to maintain high hardnesses at elevated temperatures; this accounts in large measure for their demonstrated resistance to sliding and rolling contact wear.

The specific selection of steels for nitriding and the necessary surface hardnesses, case depths, and core properties for the nitrided part all depend upon the service conditions, type of wear, size, contact stresses, and load-carrying requirements. A rather broad, but convenient, separation involves division between those applications in which wear alone is the major design criterion, and those in which both wear resistance and a higher load-carrying capacity are required. Several material types, their applications and the heat treating cycles used are shown in the M-P Fact Sheet on the opposite page.

Fig. 1 – Gear Box Containing Nitrided Vascojet 1000 Gears for Operation at Elevated Temperatures. These gears, which were nitrided to a Rockwell C-70 hardness at the surface, operated several hundred hours at 500° F.

The Mechanism of Nitriding

Amenability of a steel to nitriding depends primarily on the type and amount of alloy present and the balance of carbon to alloy in the steel. Because of this characteristic, plain carbon steels are rarely nitrided. Although a hard surface layer rich in iron-nitrogen compounds is formed, support from matrix and core is weak, and the case chips and spalls away.

When strong nitride formers (such as chromium, molybdenum and vanadium) are added to medium-carbon steels, two important effects are produced. First, alloy nitrides can form to produce high surface hardness. Second, the strength and toughness of the case matrix and the core are improved to provide a case with greater resistance to crushing loads. Representative steels in this class include A.I.S.I. 4140, 4340 and 6150.

Although adequate for many wear applications, the above steels attain hardness levels of only Rockwell C-50 to 60 because of their relatively lean alloy content. Also, the alloying

*Metallurgical Engineer, Sundstrand Aviation Div., Sundstrand Corp., Rockford, Ill.

M P Fact Sheet — Treatments and Applications for Selected Nitriding Steels

Steel	Prenitriding Treatment	Nitriding Treatment	Rockwell Hardness		Case Depth	Applications
			Case	Core		
4140	A(1550° F.), OQ & T(1000° F.)	48 hr., 975° F.	C 53–58	C 35–40	0.025–0.035 in.	Gears, shafts, splines, high-temperature bearing cages
4340	A(1550° F.), OQ & T(1000° F.)	48 hr., 975° F.	50–55	35–40	0.025–0.035	Gears, drive shafts
135 Mod. (a)	A(1750° F.), OQ & T(1200° F.)	48 hr., 975° F. (b)	65–70	30–35	0.020–0.025	Dynamic face seals, control pistons, splined drive shafts, valve stems and sleeves
5 Ni, 2 Al (c)	A(1650° F.), OQ & ST(1275° F.)	48 hr., 975 + 1025° F. (d)	65–68	40–45	0.015–0.022	Gears and lightly loaded bearings for elevated temperature
H11	A(1825° F.), AC & MT(1050° F.)	70 hr., 960 + 980° F. (d)	67–72	48–52	0.015–0.020	High-temperature power gears, shafts, pistons
H11 0.2 C	A(1825° F.), AC & MT(1025° F.)	70 hr., 960 + 1020° F. (d)	72–77	45–50	0.015–0.020	Dynamic face seals for high temperature
M50	A(2075° F.), AC & MT(990° F.)	2-35 hr., 975° F.	70–75	62–64	0.001–0.008	Hydraulic motor and pump pistons
M2	A(2250° F.), OQ & MT(1075° F.)	2-35 hr., 975-1020° F. (e)	70–75	62–66	0.001–0.008	Hydraulic motor end caps
300 series stainless	Annealed	16-20 hr., 975-1020° F. (e)	75	B 85	0.001–0.003	Adjusting screws, governor flyweights and axles, valve stems and sleeves, actuating shafts

Symbols: A: austenitize; OQ: oil quench; AC: air or atmosphere cool; T: temper; MT: multiple temper; ST: solution treat.

(a) Nitralloy steel.

(b) Two-stage cycle also commonly used.

(c) International Nickel Co. steel.

(d) Two-stage cycle: about 20% of the time at lower temperature; balance at higher temperature. If nitrided in an ammonia atmosphere, dissociation is varied 15 to 20% in first stage to 80 to 83% in second stage.

(e) Commonly run in single stage within noted range.

elements, chromium, molybdenum and vanadium, form stable carbides as well as nitrides. During the necessary pre-nitride hardening treatments, the amount of alloy available for the nitriding reaction is reduced because alloys precipitate from solid solution as carbides.

Grades Containing Aluminum

The addition of the strong nitride former, aluminum, to certain low-alloy steels results in special nitriding grades like Nitralloy 135 modified. Aluminum reduces the problem of alloy removal by carbide precipitation since it does not form a carbide. Thus, it remains in solid solution and is capable of reaction after pre-nitride treatments.

While modifications of this type provide higher surface hardness (ranging between Rockwell C-65 to 70), the case may be inadequately supported by the core for certain high-load applications. This is because the hardened structure is heavily tempered during the long 1000° F. nitriding treatment, with attendant reduction in core strength characteristics. To combat this tempering effect, nickel is added to the aluminum-bearing steels as in Nitralloy N or Inco's 5 Ni, 2 Al material. This makes it possible for the core to age harden during nitriding, thus providing better case support.

Nitriding H11 Steel

Higher alloy compositions, represented by modifications of A.I.S.I. H11 tool steel, offer interesting possibilities where very high surface hardness, wear resistance and load-carrying abilities are needed. This class is useful for parts which are to operate at high temperatures.

In secondary hardening steels of this type, the tempering temperatures used in providing maximum core tensile properties are 50 to 100° F. above 1000 F., the highest nitriding temperature normally used. Therefore, parts may be prehardened to selected strength levels without concern about *(Continued on p. 138)*

What Alloy Shall I Use . . .

for High-Temperature Applications (Above 1200°F.)?

By WARD F. SIMMONS*

Iron, nickel, and cobalt-base superalloys are the major structural materials for applications between 1200 and 1800° F. The alloys are likely to remain the only metallic materials for use at high temperatures under oxidizing conditions.
(A-general, I-66; SGA-h, SGB-s, 17-57)

HIGH-STRENGTH ALLOYS for use at elevated temperatures, often called superalloys, are divided into three groups: Iron, cobalt, and nickel-base alloys. Applications for superalloys generally fall in the range of 1200 to 1800° F. and extend sometimes up to 2000° F.

Rate of Progress

The first gas-turbine engine operated with a turbine blade temperature of about 1300° F. Today, jet engines employ maximum blade temperatures of about 1750° F., an increase of 450° F. in about 20 years, or an average increase of about 22.5° F. per year. At first, this may seem like a slow rate of increase considering the large amount of research that has been done to improve superalloys for high-temperature service. However, one should compare the figure of 22.5° F. per year with 14° F. per year – the rate of increase in steam power generating plants in which operating temperatures have gone from 700° F. to 1200° F. since 1924.

Actually, improvements in superalloys have far outstripped the predictions of the experts. In 1945 the top temperature for these alloys at high stress levels (such as for jet engine blades) was expected to reach 1500 to 1550° F. In 1950 the experts could see temperatures of 1700° F. but today it appears that 1900° F. may not be the final maximum temperature. It is interesting to note that the significant improvements made since 1952, mostly in the nickel-base alloys, have come after almost all government support for research was discontinued.

The strongest of the early superalloys were iron-base alloys, such as 16-25-6 and 19-9 W Mo. The cobalt-base alloys, Vitallium (a dental alloy, and later its modification HS-21), S-816, and X-40 (HS-31) soon took over as the strongest alloys available, only to give up the lead to the nickel-base alloys. Today, the strongest high-temperature structural alloys available, both wrought and cast, are nickel-base materials. In Great Britain the cobalt-base alloys never were important; the British went directly from the iron-base alloys to the nickel-base Nimonics.

Factors in Selection

When choosing a superalloy for a specific application, an intimate knowledge of the environment and conditions of service, as well as the physical and mechanical properties of the

*Chief, Metals Evaluation Group, Battelle Memorial Institute, Columbus, Ohio. The editors acknowledge the assistance of the following who provided illustrations for this article: Continental Aviation & Engineering Corp., Haynes Stellite Co., Pratt & Whitney Aircraft and Wyman-Gordon Co.

alloy, is necessary. In general, high-nickel alloys should be avoided in the presence of sulfur-containing compounds, especially sulfates. High-chromium alloys are not satisfactory in high vacuum because they will become depleted of chromium. Alloys containing cobalt should not be used in nuclear applications where the neutron absorption cross section must be kept as low as possible.

Chromium increases oxidation resistance of the superalloys but decreases strength somewhat. The strongest of the new cast nickel-base alloys contain only 10 to 13% Cr to increase the solubility of $Ni_3(Al, Ti)$ in the matrix. These alloys may need help to withstand oxidizing or sulfur-containing atmospheres. An aluminizing treatment provides a high degree of resistance to sulfate attack and improves resistance to oxidation and thermal fatigue.

In general, creep resistance is improved by an increase in grain size but improved fatigue strength, including thermal fatigue, is obtained with fine grains. Thus, the heat treatment should be selected with service conditions in mind. For many alloys, one heat treatment may be selected for optimum short-time strengths and another for long-time creep properties.

The superalloys are available in billets, bars, forgings, plate, sheet, strip and castings, although most alloys are not available in all forms. Properties of the important superalloys used today are given in the M-P Fact Sheets which accompany this article.

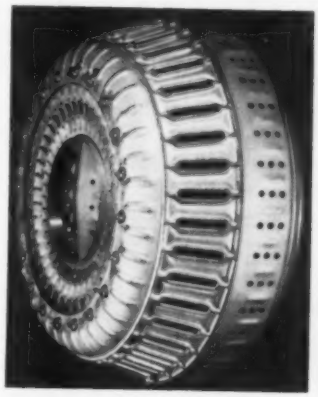
Iron-Base Alloys

The term "iron-base" is used to include three types of alloys: *(a)* The modified stainless type strengthened by adding carbide-forming elements, such as molybdenum, tungsten, columbium, and titanium; *(b)* heat-treatable or precipitation-hardening alloys; and *(c)* the more complex Fe-Cr-Ni-Co alloys.

Alloys of the first type, represented by 16-25-6 and 19-9DL, are not substantially hardened or strengthened by heat treatment and have been used principally in the "hot-cold worked" or "warm worked" condition. Final finishing at 1200 to 1500° F. with a reduction of from 20 to 40%, followed by stress relieving at 1200 to 1350° F., yields the optimum properties for service below 1300° F. Better creep and rupture properties for long-time service above 1300° F. are obtained by a solution and aging treatment.

Alloys of the second type, such as A-286,

Forging a Turbine Shaft of A-286



Combustion Shell of Hastelloy X

Nozzle Vane of Alloy HS-21

Astroloy Forging

Large Conical Shaft of René 41

Properties and Applications for Nickel-Base Superalloys

Alloy	Nominal Chemical Composition, %												
	C	Mn	Si	Cr	Ni	Co	Mo	W	Cb	Ti	Al	Fe	Other
G-157	0.06	1.25	0.40	27	Bal.	–	1.5	1.5	–	2.0	0.75	6.0*	–
J-1500, M-252	0.15	0.5	0.5	20	Bal.	10	10	–	–	3.0	1.0	–	–
GE-B-129(c)	0.06	0.4	0.4	5	Bal.	–	15	–	2	–	6.0	4	0.5 B
M-600	0.08	–	–	19	55.5	–	7	–	–	2.3	1.1	13	–
I-1360(c)	0.10	–	–	10	70.5	–	5	–	2	–	6.0	4.5	0.3 B
DCM	0.08*	0.10*	0.15	15	Bal.	–	5.25	–	–	3.5	4.6	5.0	0.08 B
René 41	0.09	–	–	19	Bal.	11	10	–	–	3.1	1.5	–	0.01 B
Astroloy	0.06	–	–	15	Bal.	15	5.25	–	–	3.5	4.4	–	0.03 B
GMR-235(c)	0.15	0.25*	0.60*	15.5	Bal.	–	5.25	–	–	2.0	3.0	10	0.06 B
GMR-235D(c)	0.15	0.10*	0.30*	15.5	Bal.	–	5.0	–	–	2.5	3.5	4.5	0.05 B
Hastelloy B	0.10	0.8	0.7	0.6	Bal.	2.5*	28	–	–	–	–	5	0.30 V
Hastelloy C	0.07	0.8	0.7	16	Bal.	2.5*	17	4	–	–	–	5	–
Hastelloy D(c)	0.12	1.0	9.0	–	Bal.	2.5*	–	–	–	–	–	1	3.0 Cu
Hastelloy N	0.06	0.8*	0.5*	7	Bal.	0.5*	16.5	–	–	–	–	5*	0.01 B
Hastelloy R-235	0.15	–	–	15.5	Bal.	2.5*	5.5	–	–	2.5	2.0	10	–
Hastelloy W	0.12*	1.0*	1.0*	5.0	Bal.	2.5*	24.5	–	–	–	–	5.5	0.6 V*
Hastelloy X	0.10	0.5	0.5	22	Bal.	1.5	9	0.6	–	–	–	18.5	–
Inconel (Inconel Alloy 600)	0.04	0.20	0.20	15.8	76.0	–	–	–	–	–	–	7.20	–
Inconel "M" (Inconel Alloy 721)	0.04	2.25	0.12	16.0	71.0	–	–	–	–	3.0	–	7.20	–
Inconel "W" (Inconel Alloy 722)	0.04	0.55	0.2	15.0	75.0	–	–	–	–	2.40	0.6	6.50	–
Inconel "X" (Inconel Alloy X-750)	0.04	0.70	0.30	15.0	73.0	–	–	–	0.85	2.50	0.80	6.75	–
Inconel "X 550" (Inconel Alloy 751)	0.04	0.70	0.30	15.0	72.5	–	–	–	1.00	2.50	1.20	6.75	–
Inconel Alloy 700	0.12	0.10	0.30	15.0	46.0	28.5	3.75	–	–	2.20	3.00	0.70	–
Inconel Alloy 702	0.04	0.05	0.20	15.6	79.5	–	–	–	–	0.70	3.40	0.35	–
Inconel Alloy 713C, (Inconel Alloy 713) (c)	0.12	0.10	0.30	11.5	74.0	–	4.5	–	2.0	0.6	6.0	1.0	–
Inconel Alloy 718	0.04	0.20	0.20	19	52.5	–	3.0	–	5.2	0.8	0.6	18	–
Waspaloy	0.07	0.7	0.4	19	Bal.	14	4.3	–	–	3.0	1.3	1	0.006 B
Waspaloy Mod.	0.05	–	–	19	Bal.	11.5	7	–	–	2.5	1.2	1	–
Udimet 500	0.08	0.75*	0.75*	19	Bal.	19.5	4.0	–	–	2.9	2.9	4*	0.01 B
Udimet 520	0.05	–	–	19	Bal.	12	6	1.0	–	3.0	2.0	–	0.005 B
Udimet 700	0.15*	–	–	15	Bal.	18.5	5.2	–	–	3.5	4.25	1*	0.1 B
Unitemp AF1753	0.24	0.05	0.10	16.25	Bal.	7.2	1.6	8.4	–	3.2	1.9	9.5	0.008 B 0.06 Zr
Nicrotung(c)	0.10	–	–	12	Bal.	10	–	8	–	4	4	–	0.05 B 0.05 Zr
TRW 1800(c)	0.09	–	–	13	Bal.	–	–	9	1.5	0.6	6.0	–	0.07 B 0.07 Zr 1.0 V
IN-100, PDRL 100(c)	0.18	–	–	10	Bal.	15	3	–	–	5	5.5	1.0*	0.015 B 0.05 Zr

*Maximum. †For rupture in 100 and 1000 hr. (c) Denotes cast alloy.

Characteristic Rupture Strengths, 1000 Psi.†						
1200° F.		1500° F.		1800° F.		
100 Hr.	1000 Hr.	100 Hr.	1000 Hr.	100 Hr.	1000 Hr.	Typical Applications
–	–	14.5	10.5	–	–	Sheet alloy
102	88	37	23	–	–	Gas turbine buckets, parts, sheet
–	–	47	29	–	–	High-temperature structural parts
–	–	28	17	–	–	High-temperature structural parts
–	–	40.5	27.3	9.4	4.8	High-temperature structural parts
–	–	–	–	20	11.5	Aircraft gas turbine blades, parts
110	102	45	29	11	–	Aircraft gas turbine parts, sheet, bolting
–	–	50	–	–	–	Jet engine components, forgings, castings
–	–	38	29	11	–	Jet engine parts
110	100	56	39	17.5	–	Jet engine parts
50	36.5	16.5	10.4	–	–	Corrosion-resistant alloy. Service under oxidizing conditions limited to 1400° F.
54	42.5	18.5	14.5	–	–	Engine parts, collector rings, combustion chambers
–	–	–	–	–	–	Corrosion-resistant alloy
42	29	13	6.8	–	–	Resistant to hot fluoride salts
85	63	40	30	8	5	Gas turbine and jet engine parts, sheet
–	–	–	–	–	–	Jet engine turbine rings; joining dissimilar metals
43	32	14.3	9.5	5.2	3.0	Jet engine parts, good oxidation resistance.
23	14.5	8.0	5.6	2.8	1.8	Combustion liners, manifolds, good oxidation resistance
55	35	17	10	–	–	Valves for aircraft engines
74	54	19	11.5	3.2	–	Sheet metal components, afterburners
80	68	28	16	3.3	2.3	Jet engine and structural parts, bolting
–	–	34	21	3.3	–	Jet engine and structural parts, bolting
100	87	43	30	6.0	3.4	Gas turbine parts
54	41	15	9	3.1	2.5	Excellent oxidation resistance to 2400° F.
101	92	68	47	20	15	Jet engine blades, parts
100	85	–	–	–	–	High-temperature structural parts
110	86	40	25	6.5	–	Jet engine blades, parts
–	–	–	–	–	–	Jet engine blades, parts
–	94	46	33	12	–	Gas turbine parts, sheet, bolting
–	–	48	33	–	–	Properties equal to Udimet 500; improved workability
–	100	58	43	16	–	Jet engine parts
115	98	47	34	10	6.5	Gas turbine components, buckets, wheels, fasteners, rings and spacers
–	–	68	45	22	13	High-strength parts
–	–	–	–	24	15	Turbine blades
–	–	75	59	25	16	Turbine blades

Discaloy and Incoloy 901, are hardened significantly by heat treatment. A distinct advantage of precipitation hardening over warm working is that higher temperatures permit easier hot working operations, such as forging, and smaller equipment can be used. Also, since strengthening is the result of heat treatment rather than warm working, the properties are more uniform throughout the forging, regardless of size or shape.

Unitemp 212 alloy, made heat treatable by the addition of 4% Ti, is one of the strongest iron-base alloys and is intended for service up to 1400° F. Small additions of columbium, boron, and zirconium retard overaging – a characteristic of alloys of this type.

Alloys of the third type, such as N-155, S-590 and Refractaloy 26, have improved oxidation resistance and suitable strength up to about 1500° F. N-155 alloy is probably the most tested of the superalloys and more data are available for it than for any other.

Cobalt-Base Alloys

Until recently the cobalt-base alloys were considered superior for service between 1600 and perhaps up to 2000° F. because of their high strength and excellent oxidation resistance in this range. Today, however, the precipitation-hardenable nickel-base alloys have the strength advantage in most of this temperature range, leaving the cobalt-base alloys the advantage only above a temperature of about 1900° F.

In early jet engines, the precision-cast, cobalt-base alloy No. 21, developed by Haynes

Properties and Applications for Iron-Base Superalloys

Alloy	Nominal Chemical Composition, %												
	C	Mn	Si	Cr	Ni	Co	Mo	W	Cb	Ti	Al	Fe	Other
A-286	0.05	1.35	0.50	15	26	–	1.25	–	–	2.0	0.2	Bal.	0.3 V
D-979	0.05	0.60	–	15	45	–	4.0	4.0	–	3.0	1.0	Bal.	0.01 B
17-14CuMo	0.12	0.75	0.50	15.9	14.1	–	2.5	–	0.45	0.25	–	Bal.	3.0 Cu
Croloy 15-15N	0.15*	2.0*	0.75*	16	15	–	1.55	1.40	1.05	–	–	Bal.	0.15 N*
CSA	0.25	4.0	0.4	18	5	–	1.3	1.3	1.0	–	–	Bal.	–
HNM	0.30	3.5	0.5	18.5	9.5	–	–	–	–	–	–	Bal.	0.23 P
Turbaloy 13	0.13	1.7	0.75	17.8	23.6	–	2.5	1.0	–	1.4	1.4	Bal.	–
J-1300, M-308	0.08	–	–	14	33	–	4.0	6.5	–	2.0	0.25	Bal.	0.25 Zr
M-813	0.08	–	–	18	35	–	4.0	–	–	2.25	1.4	Bal.	–
Hastelloy F	0.05*	1.50	1.00*	22	45.5	2.5*	6.5	1.0*	2.0	–	–	Bal.	–
Incoloy (Incoloy Alloy 800)	0.04	0.75	0.35	20.5	32	–	–	–	–	–	–	46.0	–
Incoloy "T" (Incoloy Alloy 801)	0.04	0.75	0.35	20.5	32	–	–	–	–	1.0	–	44.5	–
Inco 804 (Incoloy Alloy 804)	0.06	0.85	0.50	29.3	42.6	–	–	–	–	0.40	0.25	Bal.	–
Incoloy Alloy 901	0.05	0.5	0.40	13	43	–	6.0	–	–	2.8	0.20	34.0	–
EME	0.10	0.5	0.7	19	12	–	–	3.2	1.2	–	–	Bal.	0.15 N
16-25-6	0.08*	1.35	0.70	16	25	–	6.0	–	–	–	–	Bal.	0.15 N
19-9 W Mo	0.10	0.50	0.60	19	9	–	0.40	1.3	0.44	0.40	–	Bal.	–
19-9 DL	0.30	1.10	0.60	19	9	–	1.25	1.2	0.40	0.30	–	Bal.	–
19-9 DX	0.30	1.00	0.55	19.2	9	–	1.50	1.2	–	0.55	–	Bal.	–
19-9 WX	0.11	–	–	20.5	8.5	–	0.50	1.55	1.30	0.20	–	Bal.	–
Unitemp 212	0.08	0.30	0.30	16	25	–	–	–	0.50	4.0	0.05	Bal.	0.07 B 0.05 Zr
Discaloy	0.04	0.9	0.8	13.5	26	–	2.75	–	–	1.75	0.10	Bal.	–
W 545	0.08*	1.50	0.40	13.5	26	–	1.5	–	–	2.85	0.20	Bal.	0.08 B
Thermenol	0.05	–	–	–	–	–	3.3	–	–	–	16	Bal.	0.3 V
G-192	0.60	8.5	0.55	22	–	–	–	–	–	–	–	Bal.	0.35 N
22-4-9	0.55	8.5	0.15	20.5	3.5	–	–	–	–	–	–	Bal.	0.4 N
HTX	0.45	8.5	0.45	21	8	–	1.5	–	–	–	–	Bal.	0.2 N 0.23 P
HTX(c)	0.45	8.0	0.50	21	8	–	1.5	–	–	–	–	Bal.	0.2 N 0.22 P
CMN	0.65	12.0	–	25	–	–	–	–	–	–	–	Bal.	0.45 N
AF-71	0.30	18	0.30	12.5	–	–	3.0	–	–	–	–	Bal.	0.2 N 0.8 V 0.2 B
AF-183	0.30	18	0.30	12.5	–	–	3.0	–	–	–	–	Bal.	0.2 N 0.8 V
16-15-6	0.07*	7.5	0.50	16	15	–	6.0	–	–	–	–	Bal.	0.35 N
S-590	0.43	1.25	0.40	20.5	20	20	4.0	4.0	4.0	–	–	Bal.	–
N-155, Multimet	0.15	1.5	0.50	21	20	20	3.0	2.5	1.0	–	–	Bal.	0.15 N
K-42 B	0.03	0.7	0.7	18	42	22	–	–	–	2.1	0.2	Bal.	–
Refractaloy 26	0.03	0.8	1.0	18	38	20	3.2	–	–	2.6	0.2	Bal.	–
Refractaloy 70	0.04	2.0	0.3	20	21	30	8.0	4.2	–	–	–	Bal.	–
Haynes No. 56	0.25	1.2	0.5	20	13	11	4.5	1.0	1.0	–	–	Bal.	–

*Maximum. †For rupture in 100 and 1000 hr. (c) Denotes cast alloy.

Characteristic Rupture Strengths, 1000 Psi.†						
1200° F.		1350° F.		1500° F.		
100 Hr.	1000 Hr.	100 Hr.	1000 Hr.	100 Hr.	1000 Hr.	Typical Applications
63	46	35	21	13	8.0	Gas turbine parts and bolting
94	76	63	44	35	22	Use to 1500° F.
43	37	26	20.5	16.5	12	Use to 1500° F.
–	–	–	18	–	10	Superheat tubing, steam piping
50	39	22.5	12.5	–	–	High-temperature structural parts
49	35	26	15.5	11	–	Low strategic alloy content
65	54	–	–	–	–	Gas turbine parts
80	63	46	32	17	–	Aircraft gas turbine parts, bolting
–	52	41	30	22	13	Similar to above
42	36	26	17	14	9	For strength and corrosion resistance
32	23	15.5	10.5	8.8	5.8	Oxidation resistance similar to Inconel but lower Ni and higher strength
33	26.1	20.1	14.7	10.8	7.0	Slightly higher strength than Incoloy
–	15	–	11	–	6.5	High-temperature structural parts
94	78	55	40	24	15	Gas turbine rotor disks
44	35	20	13	–	–	Steam turbine bolting and valve stems
45	34	25	17	13.5	9	Gas turbine parts
41	34	28.5	–	11	–	Use to 1350° F.
44	37	22	17	13	8.6	Gas turbine parts and duct work, high-temperature steam service, oil refineries
52.2	42	–	–	–	–	Same as above, alloy does not contain Cb
–	–	–	–	–	–	For welding 19-9 DL and similar alloys
100	88	63	42.5	–	–	High strength and corrosion resistance to 1400° F.
52	41	30	20	15	–	Gas turbine parts and bolting
80	65	49	37	–	–	Gas turbine parts and bolting
19.3	10.0	–	–	–	–	Heat-resistant uses
42	–	27	17	15	8.5	Exhaust valve service
45	36	28	18	14	8	Steam valves, gas turbine parts
68	53	36	28	19	–	High-temperature structural parts
51	42	42	33	26	19	High-temperature structural parts
65	55	25	18	13	10	Low strategic alloy content
69	54	40	26	22	12	High-strength sheet parts up to 1500° F. Low strategic alloy content
53	38.5	26.5	–	10.5	–	Low strategic alloy content
60	40	30	20	–	–	Gas turbine compressor parts
50	38	32	25	22	16	Gas turbine parts
52	43	30	23	20	16	Jet engine combustion chambers, afterburners, tailpipes, gas turbine parts
66	40	37	27	17.5	11	Gas and steam turbine parts, bolting
80	63	51	38	27	18	Gas turbine parts, blading, bolting
56	42	33	24	19	15	Gas turbine parts, bolting
49	39	30	23	17.5	12	Uses similar to N-155, tailpipes, heat treating fixtures

Stellite Co., was an important bucket and nozzle vane alloy. However, it was soon replaced by the stronger Haynes No. 31 alloy, and the forged cobalt-base alloy, S-816. The sheet and forging alloy L-605 (HS-25) is probably the most widely used cobalt-base alloy today. It is employed in jet-engine afterburner parts, burner liners, nozzle diaphragm vanes, exhaust cone assemblies and has been selected as the structural material for lower surface panels of the Dyna-Soar hypersonic vehicle (see *Metal Progress*, March 1961, p. 90), where the maximum temperature is expected to be 2000° F.

Strengthening Mechanisms

The cobalt-base alloys depend upon solid-solution hardening and often on a dispersion of stable carbides for their strength at high-temperatures. Molybdenum, columbium, tantalum, and particularly tungsten are the alloying elements most often employed with chromium and nickel in the cobalt-base alloys. A boron addition to S-816 has given the alloy improved high-temperature mechanical properties, while titanium is an important addition in the two wrought alloys J-1570 and J-1650.

No satisfactory intermetallic system of precipitation hardening, comparable to the function of $Ni_3(Al, Ti)$ in nickel-base alloys, has been developed for cobalt-base materials. Nor does vacuum melting of cobalt-base alloys improve mechanical properties to the extent it does for the nickel-base superalloys.

Nickel-Base Alloys

Today, the nickel-base alloys are the most important

Alloy	Nominal Chemical Composition, %												
	C	Mn	Si	Cr	Ni	Co	Mo	W	Cb	Ti	Al	Fe	Other
S-816	0.38	1.20	0.40	20	20	Bal.	4	4	4	–	–	4	–
S-816(c)	0.38	1.20	0.40	20	20	Bal.	4	4	4	–	–	3	–
S-816 + B(c)	0.40	1.00	0.40	20	20	Bal.	4	4	4	–	–	3	1.0 B
V-36	0.27	1.00	0.40	25	20	Bal.	4	2	2	–	–	3	–
AF-94	0.12	1.20	–	15	10	56	5	10	1	–	–	2	–
WF-11,L605, HS-25	0.10	1.50	0.50	20	10	Bal.	–	15	–	–	–	–	–
WF-31	0.15	1.42	0.42	20	10	Bal.	2.6	10.7	–	1.0	–	–	–
J-1570	0.20	–	–	20	28	38	–	7	–	4.0	–	2	–
J-1650	0.20	–	–	19	27	Bal.	–	12	2.0 Ta	3.8	–	–	0.02 B
X-40, HS-31(c)	0.50	0.50	0.50	25	10	Bal.	–	7.5	–	–	–	1.5	–
X-63(c)	0.40	–	–	23	10	58	6	–	–	–	–	1.0	–
HS-30 422-19(c)	0.45	0.60	0.60	26	15	Bal.	6	–	–	–	–	1.0	–
HS-36,L251(c)	0.40	1.2	0.50	19	10	Bal.	–	15	–	–	–	1.0	0.03 B
HE-1049(c)	0.40	0.8	0.8	26	10	Bal.	–	15	–	–	–	3.0*	0.40 B
Haynes No. 151(c)	0.50	1.0*	1.0*	20	–	Bal.	–	12.7	–	–	–	–	0.05 B
W152(c)	0.45	0.50*	0.50*	21	1.0*	Bal.	–	11	2.0	–	–	2.0	–
Nivco-10	0.05*	0.35	0.15	–	22.5	Bal.	–	–	–	1.8	0.22	1.0*	1.1 Zr
HS-21(c)	0.25	0.60	0.60	27	3	Bal.	5	–	–	–	–	1.0	–

*Maximum. †For rupture in 100 and 1000 hr. (c) Denotes cast alloy.

of the superalloys in the 1500 to 1800° F. range. Usually included in this group are the alloys containing over 50% Ni. They derive their high-temperature strength from both precipitation hardening and solid-solution strengthening. Precipitation hardening results from the addition of aluminum and titanium which form the compound $Ni_3(Al, Ti)$. Solid-solution strengthening is accomplished by the addition of molybdenum or tungsten.

Cobalt, boron, and zirconium are important constituents of some of the nickel-base alloys. Cobalt raises the solvus temperature of alloys hardened by $Ni_3(Al, Ti)$ and thus elevates the useful working temperature. Boron and zirconium are added in small controlled amounts to improve creep-rupture properties and hot workability. Excessive amounts of these elements have a deleterious effect on creep-rupture properties and cause hot shortness by forming a low-melting phase at the grain boundaries.

Improvements Due to Vacuum

Vacuum melting has been responsible for much of the recent progress made in development of nickel-base alloys. By preventing the formation of aluminum and titanium oxides and nitrides, thus retaining all of the aluminum and titanium for precipitation as $Ni_3(Al, Ti)$, vacuum processing has improved the properties of the alloys and has permitted an increase in the total aluminum and titanium contents from a maximum of 3.7% in 1953 to 10.5% today.

Vacuum melting permits closer control of alloying additions, particularly boron and zirconium, and removes elements having low melting points, such as lead and bismuth, which have a particularly harmful effect on workability. The prevention of oxide and nitride formation is of less importance in the cobalt-base superalloys because the alloying elements that participate in carbide formation are relatively abundant.

In most nickel-base superalloys, iron is held to a minimum because it reduces somewhat the solubility of aluminum and titanium in the solid-solution matrix. It also reduces oxidation resistance, particularly at high temperatures.

Overaging Minimized

A unique advantage which nickel-base alloys, hardened with aluminum and titanium, have over other age-hardening alloy systems is the reversibility of the hardening reaction. In other alloy systems, overheating causes overaging; the alloy must then be re-heat treated to achieve the original strength level. In nickel-base alloys, overheating dissolves the $Ni_3(Al, Ti)$ pre-

Characteristic Rupture Strengths, 1000 Psi †						
1200° F.		1500° F.		1800° F.		
100 Hr.	1000 Hr.	100 Hr.	1000 Hr.	100 Hr.	1000 Hr.	Typical Applications
60	46	25	18	–	–	Jet engine buckets, bolting, springs
56	44	28	21	11	6.5	High-temperature castings
86	78	44	32	14.5	7.8	High-temperature castings
–	–	23	18	8.5	5	High-temperature sheet uses
–	–	30	22	10	–	High-temperature bar alloy
70	54	24	17	7	3.8	Jet engine parts, good sheet alloy
–	–	25	18	–	–	High-temperature sheet alloy
95	78	33	24	–	–	Gas turbine parts
–	82	46	33	13	–	Jet engine parts; one of strongest wrought alloys
56	51	28	22	11.3	9.8	Gas turbine blades, parts
54	45	24.3	17.7	8	–	Gas turbine blades, parts
–	–	28.6	21.7	10	7.1	Gas turbine parts
–	–	29	25.5	10.5	7.2	Gas turbine parts
–	–	45	35	–	–	Gas turbine parts
73	68	37	33	14	11.5	Gas turbine blades, vanes, integrally cast turbine wheels
–	–	–	–	11.5	7.8	Gas turbine parts
54	43	–	–	–	–	Steam turbine blades, high damping
52	42	20	13.5	9.4	7.0	Gas turbine blades, parts

cipitate, but as the temperature is lowered, re-precipitation occurs and most of the original strength of the alloy returns. As a result of this characteristic, these alloys can be heated above the aging temperature in service without any serious consequence, provided that the overheating is neither repetitious nor severe enough to dissolve carbides which will re-precipitate in the grain boundaries to produce a brittle condition.

With strong nickel-base sheet alloys, such as René 41, where good formability and weldability are desired, extreme care should be exercised to prevent excessive solution of the M_6C carbides during annealing treatments or in service. Since the M_6C particles begin to dissolve between 2050 and 2100° F., the solution temperature for these alloys should be limited to 2050° F.

The Future

Advances in the development of improved superalloys have exceeded expectations, but needs for the future appear to be as pressing as ever. The iron and cobalt-base systems have not enjoyed the same rate of improvement in properties as has the nickel-base system. Continued research can be expected to improve the strength of the iron and cobalt-base alloys, particularly the cobalt system, since cobalt enjoys a melting-point superiority of some 70° F. compared with nickel. Alloys may be developed which are strengthened by means other than the precipitation of carbides or gamma prime, Ni_3 (Al, Ti), to achieve stability at higher temperatures.

Improved thermal - fatigue resistance of high - strength nickel-base alloys is needed for aircraft turbine blades. The transient thermal stresses developed in the blade during starting or stopping of the engine lead to failure by thermal - fatigue cracking after running periods much shorter than would be expected from the rupture strength of the alloys.

Vacuum melting may be applied to alloy combinations that have been tried in the past but which were discarded as being too brittle.

Simple Alloy Systems

At temperatures above 1800° F., the long-time strength of complex alloys is not significantly greater than that of the simpler single-phase binary or ternary alloys. It is expected that simple alloys will be developed for use above 1800° F. which will take advantage of the combination of strength, formability, weldability, oxidation resistance, and thermal-fatigue resistance possessed by single-phase alloys.

Dispersion hardening or strengthening deserves another look because metal-metal oxide alloys produced by powder metallurgy techniques offer the possibility of higher melting temperatures. The refractory oxides employed for dispersion strengthening do not lower the melting point of the matrix as soluble alloying elements do.

Superalloys are here to stay. No matter how high the service temperatures of the refractory metals may go, superalloys will be required as the major structural materials for applications between 1200 and 1800° F. They are likely to remain the only metallic materials for use up to 2200° F. under oxidizing conditions.

What Refractory Metal Shall I Use . . .

for Ultrahigh-Temperature Applications (Above 1800° F.)?

*By D. J. MAYKUTH and H. R. OGDEN**

Today, on a strength basis, molybdenum alloys appear superior to the other available refractory metal alloys up to about 2800° F. At higher temperatures the strength advantage shifts to tungsten alloys. The major advantages offered by columbium and tantalum alloys are superior forming and welding properties and improved low-temperature ductility. (A-general, I-66; EG--d37, 17-57)

TODAY, ONLY FOUR METALS QUALIFY for large-scale structural applications above 1800° F. These, in order of increasing melting point, are columbium (4379° F.), molybdenum (4730° F.), tantalum (5425° F.) and tungsten (6170° F.).

About 1946, the need for more efficient materials for jet engines led to the first serious development of high hot-strength metals and alloys outside of the class of iron, nickel, and cobalt-base alloys discussed in the previous article. Because of its high melting point and proven reserves, molybdenum was selected as the first member of the so-called "refractory-metal" class. In the mid-'50s, the discovery of widespread columbium reserves and the promise of a lower price aroused the first real interest in this metal for high-temperature applications. The resulting development programs have led to spirited competition of columbium alloys with molybdenum alloys which is very much in evidence today.

Hot Structures

The advent of the missile age brought with it a demand for metallic components capable of withstanding flame temperatures over 4000° F. While molybdenum was the first natural choice, the trend toward higher temperatures has forced the development of production techniques for tungsten to the point where this metal has, for the first time outside of the electronics field, become important as a structural metal.

The position of tantalum as a high-temperature metal has been quite uncertain. It is much less available than either columbium, molybdenum or tungsten and is almost as heavy as tungsten. Because of these factors and an anticipated overlap in the high-temperature properties of its alloys with those of columbium and molybdenum, interest in tantalum alloys has lagged behind these other materials.

Behavior of the Unalloyed Metals

As can be surmised from their relative positions in the Periodic Chart, columbium and tantalum (both Group V metals) share many common characteristics as do molybdenum and tungsten (Group VI metals). Thus, while all four metals are reactive with oxygen, nitrogen, and carbon, columbium and tantalum show much greater solubilities for these impurities than do molybdenum and tungsten. The latter are inert to hydrogen while the former, in critical temperature ranges, can absorb large amounts of hydrogen resulting in serious embrittlement.

Molybdenum and tungsten both form vola-

*Mr. Maykuth is assistant chief and Mr. Ogden is chief, Nonferrous Metallurgy Div., Battelle Memorial Institute, Columbus, Ohio. The editors acknowledge the assistance of the following who provided the illustrations for this article: Climax Molybdenum Co., Marquardt Corp., New England Valve Corp., Oregon Metallurgical Corp., Superior Tube Co., Wyman-Gordon Co.

tile oxides at relatively low homologous temperatures. While the oxides of columbium and tantalum are quite stable, they are not protective at elevated temperature. As a result, all four metals oxidize severely when heated in air above 1200° F., and protective coatings must be employed for effective performance in oxidizing environments.

Both columbium and tantalum show a high degree of low-temperature ductility. Tantalum is superior in this respect since it remains ductile at liquid-hydrogen temperature (−423° F.). Columbium undergoes a transition from ductile to brittle behavior around −325° F. The transition temperatures of molybdenum and tungsten are more sensitive to metal purity and processing variables and occur at appreciably higher levels (−50° F. to 100° F. for molybdenum and 350° F. to 850° F. for tungsten).

Unlike columbium and tantalum, optimum low-temperature ductility in molybdenum and tungsten is achieved when these metals are in the wrought condition. Recrystallization of molybdenum or tungsten results in a marked increase in their transition temperature. This has great practical significance for molybdenum, since the room-temperature ductility normally shown by this metal in the wrought form can be seriously reduced or lost upon recrystallization. Consequently, for applications in which optimum ductility at low temperatures must be retained, neither molybdenum nor tungsten should be heated to temperatures at which recrystallization will occur. The recrystallization temperatures of all four of these metals vary with both metal purity and the amount of prior cold work. Generally, however, these temperatures increase for columbium, molybdenum, tantalum and tungsten in the approximate order listed, as shown in the M-P Fact Sheet on p. 94.

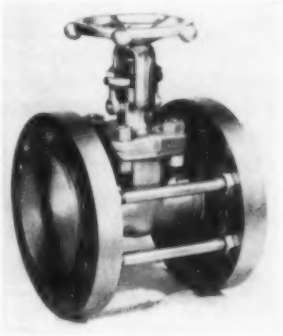
Methods for Fabrication

Molybdenum and tungsten are appreciably more difficult to fabricate than columbium and tantalum. However, fabrication difficulties can be minimized with powder metallurgy techniques. Indeed, much molybdenum and all present wrought commercial forms of tungsten are still being produced this way.

Techniques have been developed for deep drawing and shear spinning all four refractory metals. These processes are more difficult for molybdenum and tungsten which require preheating above their transition temperatures to obtain the necessary degree of plasticity.

All four metals can be joined satisfactorily

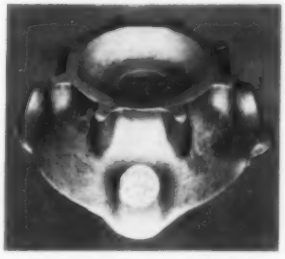
Welded Combustion Chamber and Nozzle of 0.5% Ti Molybdenum Alloy



Valve of Molybdenum

Molybdenum Tubing

Tungsten Part Machined From Centrifugal Casting



Forging of 1% Zr-Cb Alloy

Nozzle Forged From Tungsten

Properties of Refractory Metals and Their Alloys

Alloy	Nominal Alloy Content, %	Status Jan. 1961	Density, Lb./Cu.In.	Recrystallization Temperature, °F.	Ultimate Tensile Strength, 1000 Psi.* 2000° F.	2200° F.	2400° F.	2500° F.	2750° F.	3000° F.	3500° F.	4000° F.
Columbium and Columbium-Base Alloys												
100Cb	0.036 O, 0.019 N, 0.024 C	Commercial	0.31	1785–2100	10.1	9.3						
FS-80	0.75 Zr	Commercial	0.311	2200	~20	–						
FS-82	33 Ta, 0.75 Zr	Commercial	0.371	2200	30	13						
Cb-65	7 Ti, 0.8 Zr, 0.11 O, 0.02 N, 0.075 C	Pilot production	0.29	–	23	15						
Cb-74(752)	10 W, 5 Zr, 0.12 O, 0.02 N, 0.03 C	Pilot production	0.33	2600–2800	52	36						
F-48	15 W, 5 Mo, 1 Zr, 0.1 C	Pilot production	0.34	2800	65	50						
F-50	15 W, 5 Mo, 5 Ti, 1 Zr, 0.05 C	Pilot production	0.33	2500	50	35						
D-31	10 Mo, 10 Ti, 0.05 O, 0.07 N, 0.06 C	Pilot production	0.292	2200	30	27						
D-41	20 W, 10 Ti, 6 Mo	Pilot production	0.32	2500	56	49						
Cb-Ta-W-Zr	24 Ta, 10 W, 1 Zr	Pilot production	0.38	2550	68	35						
C-103	10 Hf, 1 Ti, 0.5 Zr	Pilot production	0.32	2200	26	–						
Molybdenum and Molybdenum-Base Alloys					2000° F.	2200° F.	2400° F.					
100Mo	0.01–0.03 C	Commercial	0.369	2100–2200	44	–	13					
Mo-0.5Ti	0.5 Ti, 0.02–0.05 C	Commercial	0.368	2450	57	37	19					
TZC	1.25 Ti, 0.15 Zr, 0.15 C	Pilot production	0.362†	2800–2900	58	54	39					
TZM	0.5 Ti, 0.08 Zr, 0.02–0.08 C	Pilot production	0.368†	2600–2900	78	65	54					
Mo-0.05Zr	0.054 Zr, 0.024 C	Advanced experimental	0.369†	2450	70	–	22					
Mo-0.5Zr	0.5 Zr, 0.02 C	Pilot production	0.368†	2650–2800	60	46	27					
Mo-25W	25 W, 0.11 Zr, 0.05 C	Advanced experimental	0.42†	2550	90	82	73.5					
Mod. TZC	1.27 Ti, 0.29 Zr, 0.3 C	Experimental	0.362†	3200	80	71	61					
Mo-1.5Cb	1.5 Cb, 0.25 C	Experimental	0.368†	2600	88	77	64					
Tungsten and Tungsten-Base Alloys					2500° F.	3000° F.	3500° F.	4000° F.				
100W	0.002–0.005 O, 0.0015–0.004 N, 0.0004–0.005 C	Commercial	0.697	2200–3000	50	20	10	6.5				
W-1ThO$_2$	1 ThO$_2$	Semicommercial	0.690†	–	48.5	37	28	14				
W-2ThO$_2$	2 ThO$_2$	Semicommercial	0.683†	–	35.5	29.5	26.5	17.5				
W-10Mo	10 Mo	Experimental	0.640†	–	44	28	11	5				
W-15Mo	15 Mo	Advanced experimental	0.615†	–	38.5	25	13.5	7				
W-25Mo	25 Mo	Experimental	0.570†	–	46	30	8	5				
W-0.38TaC	0.38 TaC	Advanced experimental	0.696†	–	51.5	31	–	–				
Tantalum and Tantalum-Base Alloys					2200° F.	2500° F.	2750° F.	3000° F.				
100Ta	0.004 O, 0.003 N, 0.004 C	Commercial	0.600	2200–2400	10	7	4	3				
Ta-10W	10 W, 0.0045 O, 0.0015 N, 0.001 C	Commercial	0.607	2730	67	22	17	9				
Ta-10Hf-5W	10 Hf, 5 W	Advanced experimental	0.589	2730	63	40	31	20				
Ta-30Cb-7.5V	30 Cb, 7.5 V	Advanced experimental	0.426	2370	60	40	27	10				

*All materials were tested in wrought or stress-relief-annealed condition except 100Cb and all tantalum alloys which were recrystallized. Ta-10W was tested in as-wrought condition.

†Calculated values.

using mechanical fasteners, brazing, and welding by resistance, fusion, or electron beam methods. Good ductility is retained in fusion-welded joints of columbium and tantalum. In tungsten and molybdenum, the structure of the fusion weld is coarse grained and usually causes a marked increase in transition temperature. Also, there is a strong tendency for molybdenum and tungsten welds to crack, especially when joining heavy sections.

At 2000° F. or greater, the strengths of columbium, tantalum, molybdenum and tungsten increase in the approximate order listed as shown by data in the M-P Fact Sheet. Even at

Rupture Strength, 1000 Psi.*		
2000° F.		2200° F.
10 Hr.	100 Hr.	10 Hr.
4.4	3.1	–
–	19	–
25	18	–
–	–	–
35	–	18.5
42	35	24
27	20	16
16	–	11
23	18	12
24	–	–
–	–	–

100-Hr.		
2000° F.	2200° F.	2400° F.
13	–	–
34	18	10
40	31	21
50	–	–
41	20.5	10.5
41	26	10
43	33	12.3
–	–	32.7
57	35	12.3

10 Hr.		100 Hr.	
Temp., ° F.	Stress, 1000 Psi.	Temp., ° F.	Stress, 1000 Psi.
2200	22	–	–
–	–	–	–
2500	29	2500	22
–	–	2700	11
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–

Refractory metals, in general, are not considered for cryogenic applications since there are other metals that have excellent strength-ductility combinations at low temperature. However, when a combination of toughness at low temperature with strength at high temperature is required, tantalum alloys may be useful. The development of tantalum-base alloys for this purpose is in its early stage and new alloys can be expected in the future. Progress in this area will be reported in next month's *Metal Progress* in an article by H. R. Ogden, chief, Nonferrous Metallurgy Div., Battelle Memorial Institute, and I. Perlmutter, Directorate of Materials and Processes, Aeronautical Systems Div., Air Force Systems Command.

2000° F., however, the strengths of pure columbium and tantalum are too low to merit consideration for most load-bearing applications. All four metals can be strain hardened appreciably through cold working. However, these strengthening effects for columbium, tantalum, and molybdenum are lost through recrystallization on heating to 2400° F.

The strength of each of these metals is also sensitive to impurity content. This is especially true of columbium and tantalum with regard to oxygen which can vary widely as a result of variations in processing the raw materials or through absorption in testing. Small amounts of oxygen, carbon, or nitrogen can have significant strengthening effects. Further, interactions of these impurities with intentional or unintentional metallic additions can exert profound effects in increasing the recrystallization temperature and strength properties by a mechanism of dispersion hardening. Because of these factors, many of the data on high-temperature strength of the refractory metal alloys should be viewed with some reservations.

Fairly intensive alloy studies are under way on all four refractory metals, and a considerably large number of promising alloys have already evolved. While few of these have as yet achieved commercial status, many have advanced to at least the point of pilot production or advanced laboratory scale-up. A summary of the compositions, status, and properties of representative alloy candidates of each of these metals is given in the M-P Fact Sheet.

Columbium Alloys

Most columbium alloys under development today fall between the extremes of the low and high-strength alloys typified by the FS-80 and F-48 alloys, respectively. Generally, the low-strength alloys tend to retain the excellent fabricability, weldability, and low transition temperature of unalloyed columbium. These alloys rely chiefly on a low zirconium addition for strengthening through dispersion hardening. Some contain tantalum or hafnium to improve oxidation resistance as well as hot strength.

Greater strengthening is achieved through use of tungsten or molybdenum (or both) as solid-solution strengtheners. The strongest columbium alloys contain these as well as zirconium, with or without intentional addition of carbon. As might be expected, these improvements in strength are offset by increased difficulties in fabrication and a decrease in ductility at low temperatures, especially for

coarse-grained, recrystallized structures obtained in fusion welding.

Molybdenum Alloys

Until recently, emphasis in developing molybdenum alloys centered almost exclusively on strain-hardened and dispersion-hardened alloys containing small additions of carbon with titanium or zirconium (or both). Alloys of this type not only show substantially higher recrystallization temperatures than unalloyed molybdenum, but have considerably improved strengths up to 2400° F. as well. Generally, the transition temperatures for these alloys are not substantially different from those of the unalloyed metal. In fact, some of these alloys (Mo-0.5Ti-0.05C) show a lower transition temperature after fusion welding.

Within the past year, interest has been aroused in the solid-solution-strengthened Mo-25W alloy. Preliminary data for this alloy indicate that it has outstanding tensile strength up to 2400° F., although its stress-rupture strength at 2400° F. is not so great as that obtained in some of the dilute Mo-Ti-Zr-C alloys.

Tantalum Alloys

Development of tantalum alloys is considerably less advanced than for columbium and molybdenum. Nonetheless, the values listed in the M-P Fact Sheet for the commercial Ta-10W and two advanced experimental alloys give a good idea of the elevated-temperature tensile strengths* which can be expected.

Comparisons of strength show that the Ta-10Hf-5W alloy has an advantage over both Ta-10W and Ta-30CB-7.5V through 300° F. Up to about 2900° F., however, strength-to-weight comparisons show that the advantage lies with Ta-30Cb-7.5V alloy due to its lower density.

Each of these three alloys shows good ductility at low temperatures as recrystallized, with Ta-30Cb-7.5V being outstanding. This alloy remains ductile in tension in liquid nitrogen (−320° F.) and has an "OT" minimum bend radius at room temperature as fusion welded.

Tungsten Alloys

Due to difficulties in preparation and fabrication, the development of tungsten alloys lags that of the other refractory metals. Nevertheless, a number of alloys have been developed which show promising strength at up to 3500° F. These include the thoriated grades and the W-0.38TaC alloy – which must be made using powder metallurgy techniques – and the W-Mo binary alloys which can be arc melted.

The peak in hot strength in the latter alloy system apparently occurs in the W-15Mo composition which retains a strength advantage over unalloyed tungsten to about 4000° F. At higher temperatures, the only alloys shown to have a significant strength advantage are the W-1ThO_2 and W-2ThO_2 alloys. Like unalloyed tungsten, the ductile-to-brittle transition temperature of each of these alloys lies well above room temperature.

On the basis of strength comparisons alone, molybdenum alloys appear superior to the other "available" refractory metal alloys up to possibly 2800° F. At higher temperatures, the strength advantage shifts to tungsten alloys. While molybdenum and tungsten are appreciably less expensive than columbium and tantalum, the greater difficulties in fabricating tend to offset their cost advantages when in the form of alloyed mill shapes.

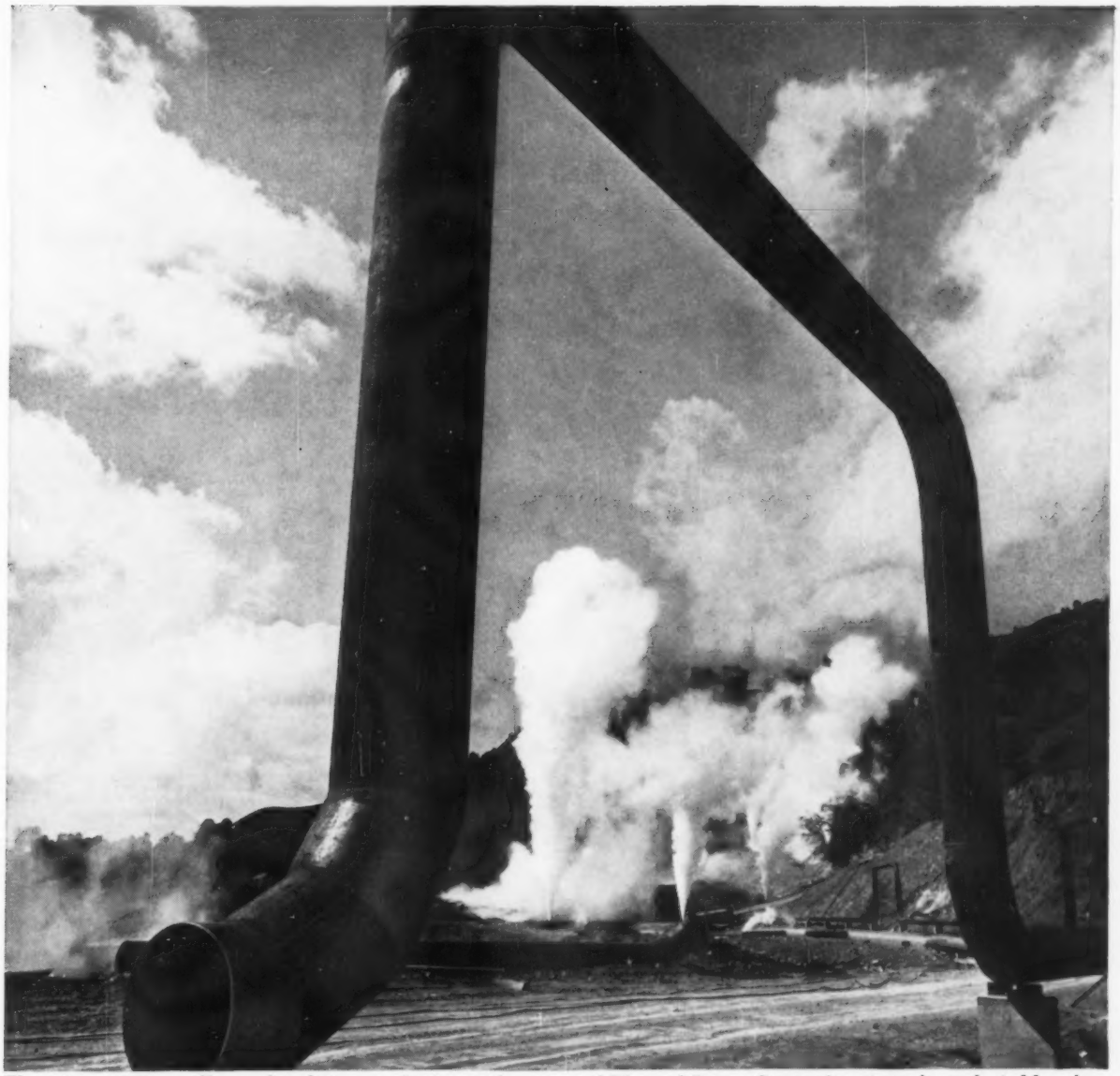
The major advantages offered by columbium and tantalum alloys over those of molybdenum and tungsten lie with better formability, weldability and improved ductility at low temperatures. Because of their lower cost and density, columbium alloys will probably be favored over tantalum alloys up to about 2400° F. At higher temperatures, it appears likely that tantalum alloys will take over the competition with molybdenum and, perhaps, tungsten.

The Future

Further improvement in the hot strengths of all of the present generation of refractory metal alloys is certain to come. It is questionable, though, whether the relative order of strengths obtained in these four base metals through alloying will be changed appreciably beyond that evidenced at present. Rather, greater emphasis will be placed on improving fabricability, low-temperature ductility, and weldability.

Several of the current columbium and tantalum alloys show improved oxidation resistance over that of the unalloyed base metals. However, none of these alloys can be regarded as oxidation resistant. Also, hopes of obtaining oxidation-resistant alloys which are workable and have high strength in either a columbium, tantalum, molybdenum, or tungsten base are practically nonexistant. Hence, protective coatings are necessary to permit any of these alloys to perform satisfactorily at high temperature in an oxidizing atmosphere.

*Stress-rupture properties on these alloys are not yet available.



These "geysers" actually consist of steam rocketing up from deep in the ground. From this well area, operated by Magma and Thermal Power Companies, steam is conducted by pipeline to The Geysers Power Plant a quarter-mile away.

Now...electric power from geysers!

Nickel in stainless steel helps make possible America's first geothermal power plant.

Here's a power plant under construction in California that will produce enough electricity for a town of 50,000 people—all from the steam of geysers.

To withstand the continuous attack of this highly corrosive steam at The Geysers Power Plant, Pacific Gas and Electric Company selected stainless steel with nickel for all points where condensed steam contacts metal.

With nickel in it, stainless steel is more than a match for this corrosive steam. This ability plays a key role in turning out power every day of the year, with virtually no maintenance in a plant designed for unattended operation.

Nickel helps metals and alloys withstand the severest conditions. Nickel-containing metals safely hold liquid oxygen at a sub-zero cold that shatters many materials. America's first nuclear-powered merchant ship uses alloys with nickel in them to contain the tremendous pressures and corrosive conditions in its power plant. And an alloy with nickel in it will enable the famous X-15 rocket ship to make the hot ride home from space without burning up.

Does your company have problems of these kinds in a product or a process? Why not write to us about them. Perhaps nickel or one of its alloys can help you.

THE INTERNATIONAL NICKEL COMPANY, INC.

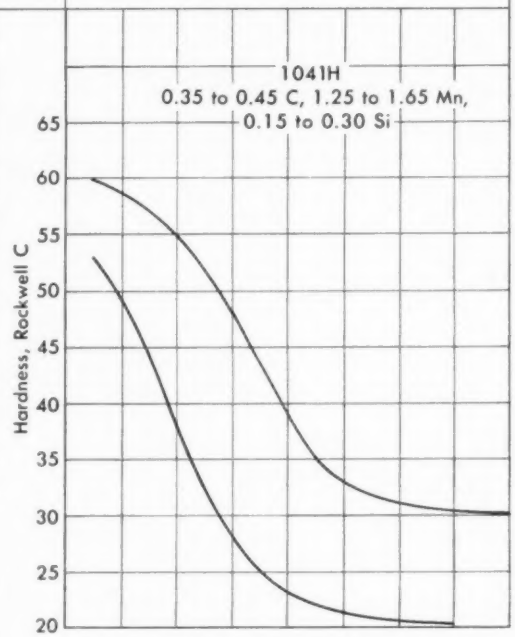
67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

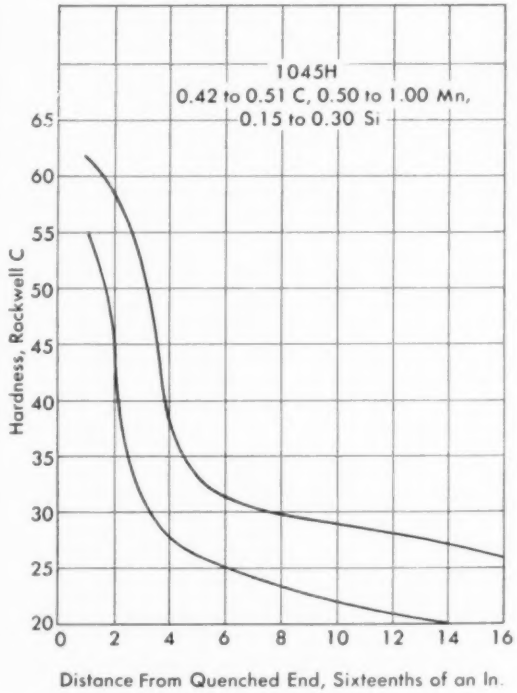
NICKEL MAKES STEEL PERFORM BETTER LONGER

Quench	Location in Round	Diameter of Round With Same As-Quenched Hardness
Mild Water	Surface	3.8
	¾ Radius From Center	1.1 2.0 2.9 3.8 4.8 5.8 6.7
	Center	0.7 1.2 1.6 2.0 2.4 2.8 3.2
Mild Oil	Surface	0.8 1.8 2.5 3.0 3.4 3.8
	¾ Radius From Center	0.5 1.0 1.5 2.0 2.4 2.8 3.2
	Center	0.2 0.6 1.0 1.4 1.7 2.0 2.4

Hardness Limits for Specification Purposes		
"J" Distances, Sixteenths of an In.	1041H	
	Max.	Min.
1	60	53
1.5	59	52
2	59	50
2.5	58	47
3	57	44
3.5	56	41
4	55	38
4.5	53	35
5	52	32
5.5	50	29
6	48	27
6.5	46	26
7	44	25
7.5	41	24
8	39	23
10	33	22
12	32	21
14	31	20
16	30	—



Hardness Limits for Specification Purposes		
"J" Distances, Sixteenths of an In.	1045H	
	Max.	Min.
1	62	55
1.5	61	52
2	59	42
2.5	56	34
3	52	31
3.5	46	29
4	38	28
4.5	34	27
5	33	26
5.5	32	26
6	32	25
6.5	31	25
7	31	25
7.5	30	24
8	30	24
10	29	22
12	28	21
14	27	20
16	26	—



Hardenability Bands for 1041 and 1045 . . . S.A.E. Recommended Practice

The hardenability bands for carbon steels reproduced here are presented in the same manner used for alloy steels and reported in the S.A.E. Standard, Hardenability Bands for Alloy H Steels. These bands are applicable to semifinished products for forging, hot rolled and cold finished bars, wire rods, and seamless tubing. Hardenability tests should be performed in accordance with the section on Hardenability Test for Shallow Hardening Steels in the S.A.E. Recommended Practice, Methods of Determining Hardenability of Steels.

A practical approach to quenching

The three most common media used for quenching steel are water, brine and oil. Water offers rapid cooling, good hardness, penetration and low cost but may cause quench cracks. And it rates low in uniformity and size retention. Brine is even faster than water. It removes heat more uniformly but it, too, produces distortion and quench cracks. Oil is milder. It does not remove heat as fast as water or brine, but will minimize distortion and cracking.

Generally speaking, plain carbon steels require a high cooling rate such as that of water or brine for maximum hardness. Most alloy steels require a lower quenching speed for hardening, with some high alloy steels, such as high-speed tool steel, hardening fully in air.

Thus, the determination of what quench to use depends on the steel analysis, the quenching speed the specific steel requires, and the physical properties called for in the finished part. As a guide, here are six distinct quenchants developed and produced by Houghton. They provide full coverage of the complete range of cooling speeds called for by various steel analyses and the physical properties required in the part:

1. **A high-speed oil** that quickly quenches critical alloy steels for maximum hardness.
2. **A general purpose oil** that provides adequate hardness, superior toughness and low distortion in a wide range of alloy steels.
3. **A martempering oil** which can be maintained at 350°F. for long periods. For interrupted quenching to provide toughness and close size tolerance.
4. **Molten salt** for interrupted quenching at temperatures up to 1000°F. . . . for martempering, austempering and patenting.
5. **An additive for water** to minimize quench cracks.
6. **A concentrate** for addition to tanks of 100° paraffine oil to improve stability and accelerate the quenching rate.

If you are looking for improved physicals, better heat treat uniformity or fewer rejects, you can get experienced advice from Houghton—a leader in metallurgy for more than 50 years.

COMMON-SENSE QUENCHING HINTS

1. Provide oil circulation so that all surfaces of parts to be quenched are exposed uniformly to the oil. Containers should be baffled. Avoid nesting of work.
2. When installing cooling coils, the water in the coils should run counter-flow to the oil to provide maximum temperature differential.
3. The quench tank should be equipped with a tight cover and a CO_2 extinguisher handy in case the oil should catch fire.
4. Avoid use of baskets in quenching where possible. It is better to drop small parts on a screen which can be lifted out of the bath. Basket congestion hinders uniform cooling.
5. Avoid temperature variation when water is the quenching medium. Hold to 20° maximum spread.
6. Distortion and quench cracks can be minimized by removing the work from the quench before it reaches the temperature of the fluid.
7. It is advisable to temper **immediately** after quenching to relieve stresses and avoid quench cracks.
8. Wherever possible oil quenched work should be cleaned prior to tempering in salt to minimize salt contamination.

Your nearby Houghton representative will gladly give you detailed information and help in analyzing your problem and recommending the quench best suited to your need. Call him or write for a copy of "Houghton on Quenching". E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa.

Houghton

INDUSTRY'S PARTNER IN PRODUCTION

Circle 1580 on Page 48-B

Have times really changed?

A lot has happened in the zinc die casting industry since 1925, the year Zamak was invented and patented by New Jersey Zinc...die casting techniques have vastly improved, the Zamak alloys have been ceaselessly researched and perfected, undreamed of applications have been pioneered. But one factor has remained consistent. When there's a zinc die casting problem to be solved, be it metallurgical or production, you look to the company whose research and technical assistance programs are still unequalled—New Jersey Zinc. And the men who know there is far more to buying metal than specifications look for the symbol of the Horse Head, for they know that New Jersey Zinc stands behind it.

NJZ

HORSE HEAD PRODUCTS

THE NEW JERSEY ZINC CO.

160 FRONT STREET • NEW YORK 38, N. Y.

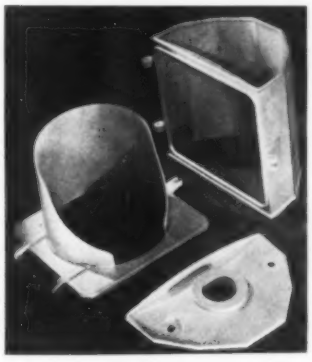
Circle 1581 on Page 48-8

What Metal Shall I Use . . .

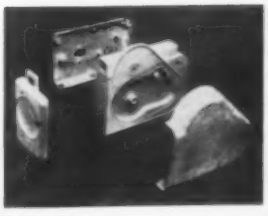
for Die Castings?

Of the major die casting alloys, those of aluminum are strongest and have the highest thermal and electrical conductivity. Magnesium alloys are lightest; zinc alloys are toughest and have the lowest melting point – which contributes to their good casting characteristics. Copper alloys are strong and corrosion resistant, but are relatively difficult to cast. (E13; Al, Mg, Zn, Cu)

Die Cast Magnesium Housing for A.C.-D.C. Converter in Aircraft

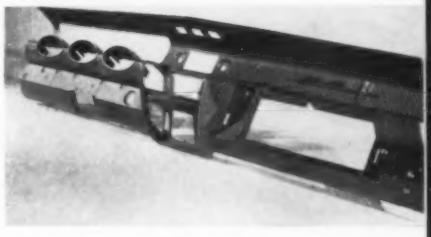


Aluminum Die Castings for Traffic Signal



Intricate Aluminum Die Castings for Movie Camera

Vacuum Cleaner Part Die Cast of Magnesium



Zinc Dash Console for 1961 Oldsmobile

SELECTION OF THE BEST ALLOY for die casting in a specific application depends upon satisfying property requirements for the finished casting at the lowest over-all cost. It should be realized that the as-cast cost per piece is often quite different from the total cost of the finished part. Machining and finishing costs frequently equal or exceed the cost of the basic casting. Also, original die cost and die life vary widely and have a considerable influence on machining and finishing operations.

In comparing the three major die casting alloys, those of aluminum have the highest electrical and thermal conductivity, and magnesium and aluminum alloys are lighter than zinc alloys. Zinc has the highest impact strength, ductility, and hardness. Most of the aluminum alloys are as strong or stronger than the zinc alloys, but zinc possesses the lowest melting point – a factor which has a favorable influence on melting costs, production rates, and die life.

Zinc Alloys

Zinc die castings can be produced with high accuracy, smooth surfaces, and in a great variety of intricate shapes. In many instances, very small, complex parts can be produced at lower cost than when screw machines are used.

Generally, all three zinc alloys in the M-P Fact Sheet

The editors wish to acknowledge the assistance of the following in preparing this report: Aluminum Co. of America, American Smelting & Refining Co., Apex Smelting Co., Dow Chemical Co., New Jersey Zinc Co., Newton-New Haven Co.

Die Casting Alloys of Aluminum, Zinc, Magnesium and Copper

Alloy Designations			Composition, %*	Typical Mechanical Properties			
				Strength			
ASTM	SAE	Commercial		Tensile	Yield	Shear	Fatigue†
Aluminum							
SC84A or B‡	306 308	380	3.0-4.0 Cu; 1.3 or 2.0 Fe; 7.5-9.5 Si; 0.50 Mn; 0.10 Mg; 3.0 Zn; 0.50 Ni; 0.35 Sn; other 0.50	A:47,000 B:46,000	23,000 23,000	27,000 28,000	20,000 20,000
S12A or B‡	305	13	0.6 Cu; 1.3 or 2.0 Fe; 11.0-13.0 Si; 0.35 Mn; 0.10 Mg; 0.50 Zn; 0.50 Ni; 0.15 Sn; other 0.25	A:42,000 B:43,000	19,000 21,000	25,000 25,000	19,000 19,000
SG100A or B‡	309	360	0.6 Cu; 1.3 or 2.0 Fe; 9.0-10.0 Si; 0.35 Mn; 0.40-0.6 Mg; 0.50 Zn; 0.50 Ni; 0.15 Sn; other 0.25	A:46,000 B:44,000	24,000 25,000	26,000 28,000	18,000 20,000
G8A	–	218	0.25 Cu; 1.8 Fe; 0.35 Si; 0.35 Mn; 7.5-8.5 Mg; 0.15 Zn; 0.15 Ni; 0.15 Sn; other 0.25	45,000	28,000	29,000	20,000
S5C	35 304	43	0.6 Cu; 2.0 Fe; 4.5-6.0 Si; 0.35 Mn; 0.10 Mg; 0.50 Zn; 0.50 Ni; 0.15 Sn; other 0.25	33,000	14,000	19,000	17,000
SC114A	303	384	3.0-4.5 Cu; 1.3 Fe; 10.5-12.0 Si; 0.50 Mn; 0.10 Mg; 1.0 Zn; 0.50 Ni; 0.35 Sn; other 0.50	48,000	24,000	29,000	20,000
Zinc							
AG40A	903	3	3.5-4.3 Al; 0.25 Cu; 0.03-0.08 Mg; 0.10 Fe; 0.007 Pb; 0.005 Cd; 0.005 Sn	41,000	–	31,000	7,000
AC41A	925	5	3.5-4.3 Al; 0.75-1.25 Cu; 0.03-0.08 Mg; 0.10 Fe; 0.007 Pb; 0.005 Cd; 0.005 Sn	47,000	–	38,000	8,000
–	–	7	3.5-4.3 Al; 0.25 Cu; 0.005-0.02 Mg; 0.075 Fe; 0.003 Pb; 0.002 Cd; 0.001 Sn; 0.005-0.02 Ni	42,000	–	–	–
Magnesium							
AZ91B	501A	–	8.3-9.7 Al; 0.13 min. Mn; 0.35-1.0 Zn; 0.50 Si; 0.35 Cu; 0.01 Ni; other 0.30	34,000	23,000	20,000	14,000
Copper							
Z30A	–	A	57.0 min. Cu; 0.25 Si; 1.50 Pb; 1.50 Sn; 0.25 Mn; 0.25 Al; 0.25 Fe; 30.0 min. Zn; other 0.50	55,000	30,000	–	–
ZS331A	–	B	63.0-67.0 Cu; 0.75-1.25 Si; 0.25 Pb; 0.25 Sn; 0.15 Mn; 0.15 Al; 0.15 Fe; other 0.50; bal. Zn	65,000	35,000	–	–
ZS144A	–	C	80.0-83.0 Cu; 3.75-4.25 Si; 0.15 Pb; 0.25 Sn; 0.15 Mn; 0.15 Al; 0.15 Fe; 0.01 Mg; other 0.25; bal. Zn	90,000	50,000	–	–

*Single values represent maximums, except as noted. ASTM limits are shown; SAE and commercial limits may differ in minor respects.
‡1.3% Fe for "A" modification; 2.0% Fe for "B" (note mechanical property variations).
†5×10^8 cycles for aluminum and magnesium; 1×10^8 cycles for zinc.

are interchangeable for most applications. Alloy AC41A (No. 5) is somewhat harder and stronger than AG40A (No. 3), has slightly better castability, but is less stable dimensionally and loses impact strength faster at elevated temperature. Claims for the newest zinc die casting alloy, No. 7, are improved surface finish, dimensional stability, and higher production rates. This is obtained by reducing the magnesium and impurity content of the alloy (to minimize hot shortness) and adding a small amount of nickel.

In many applications, zinc die castings are used without any applied surface finish or treatment. However, there are a variety of methods – including the "Cronak" conversion coating process – which can be used to improve corrosion resistance or to provide a good base for paint. Electroplating with copper, nickel, chromium, brass, gold and silver is also employed. In plating, a standard copper-nickel chromium plate provides the best combination of corrosion protection and improved appearance.

(Separately Cast Test Bars)			Solidification Range, °F.	Applications
Charpy Impact, Ft-Lb.	Elongation, %	Brinell Hardness (500 Kg.)		
3.0 3.0	3.5 2.5	80 80	1070-950	General-purpose applications (parts for autos, appliances, business machines) where good castability and mechanical properties are required. Examples are transmission cases and clutch housings for automobiles; vacuum cleaner, food mixer, and washer components; and parts for hand tools, instruments, cameras and typewriters.
3.0 3.0	3.5 2.5	70 70	1085-1060	Large die castings with complex shapes and thin walls, such as automotive engine blocks and water-pump bodies. Also gas-meter bodies, instrument cases and other industrial parts requiring maximum corrosion resistance.
3.0 3.0	3.5 2.5	80 80	1105-1035	Intricate castings such as outboard motor parts, fire alarm boxes, and textile machinery. Corrosion resistance is good.
7.0	5	80	1140-990	Applications requiring optimum combination of strength, ductility, corrosion resistance and finishing properties. Black anodized gun parts, stair treads, roller skates, and fittings for summer furniture. Castability is poor.
8.0	9	65	1165-1060	Cookware and other corrosion-resistant applications. This alloy has best ductility.
2.5	2.5	85	1060-950	Large, thin-walled castings of complex design. Alloy has excellent fluidity and is easy to die cast.
43	10	82	728-717	Automotive: carburetors, fuel pumps, grilles, panels, brackets, trim and parts for speedometers, horns, heaters and air conditioners.
48	7	91	727-717	Appliances: Parts for washers, dryers, oil burners, motors and kitchen equipment. Parts for business and vending machines such as cams, gears, wheels, pulleys, brackets and levers.
—	20	85	728-717	Generally, these three alloys can be used for the same applications. A faster production rate is achieved using Alloy No. 7 and improved surface finish is claimed.
2.0	3	63	1105-875	Automotive: crankcases, clutch housings, fuel pumps, dash panels and fan spacers. Components for cameras and projectors, electrical motors, business machines, chain saws, vacuum cleaners and typewriters.
33	15	125	1725-1675	
36	25	120	1650-1600	Plumbing goods, valves, air and gas fittings, gears and bearings, electrical components, as well as general hardware and ornamental uses.
40	20	170	1650-1600	

Aluminum Alloys

Die casting alloys based on aluminum are light, easy to machine, and resistant to a wide range of corrosive environments. The alloys will take and hold a high polish, and anodic coatings can be applied to protect the surface from wear and abrasion. For decorative effects, however, special alloys free of silicon and copper must be used.

The first two alloys in the M-P Fact Sheet are most widely used. Alloy SC84A is a general purpose alloy having good castability and mechanical properties. It is also the least costly of the aluminum group. The high-silicon alloy, S12A, has excellent castability (due to its superior fluidity and freedom from hot shortness), is resistant to corrosion, and castings are pressure tight.

Alloy SG100A provides somewhat better corrosion resistance than SC84A (along with equivalent mechanical properties), but the cast surface is inferior and sometimes requires painting. As far as alloy G8A is concerned, it has

Fig. 1 – Die Cast Magnesium Crankcase After 65,000 Miles Service. (Volkswagen-Dow)

the best combination of properties and finishing characteristics, but it is difficult to cast and is not utilized extensively.

Although S5C is difficult to die cast, its good ductility is an advantage in assembly operations involving forming or upsetting. Alloy SC114A has excellent fluidity and is easy to die cast – ideal characteristics for the production of complex, thin-walled castings.

The corrosion resistance of aluminum is such that die castings may be used with an as-cast surface in most instances. They may also be mechanically or chemically finished, painted, and to a limited extent electroplated to enhance the surface appearance.

Versatile Magnesium Alloy

Magnesium is the lightest of all the die casting alloys. It is relatively easy to machine, and its good castability and high strength-to-weight ratio are other factors of interest to the design engineer and production man.

The one die casting alloy, AZ91B, is a general-purpose magnesium alloy that possesses casting characteristics and mechanical properties suitable for many applications. Most of the physical properties of the alloy are satisfactory over a wide temperature range, and extremely low temperatures have no adverse effects. The corrosion resistance of magnesium die castings is relatively low in moist or sea atmospheres; this means a chemical treatment such as a chromium pickle is usually required prior to the application of the priming coat. An important application for magnesium die castings, where corrosion is a problem, is in crankcases for automobile engines. Figure 1 illustrates the excellent condition of a Volkswagen crankcase after 65,000 miles of service.

Production rates possible with magnesium exceed those of aluminum and are comparable to zinc. Automatic feeding of molten magnesium to cold-chamber machines by metering or vacuum systems permits casting at rates limited only by the cooling rate of the steel dies. With small castings, production rates up to 700 an hour have been achieved.

Using standard engineering approaches, magnesium castings will weigh about 70% as much as aluminum and 35% as much as zinc for the same performance requirements. This weight saving is beneficial in several areas, including shipping costs.

Copper Alloys

While copper-base die castings offer excellent mechanical properties, they are more expensive. Melting points of alloys are much higher, thus increasing die costs and reducing die life. The high pressures required in die casting copper alloys necessitate extensive hydraulic equipment on which maintenance is costly.

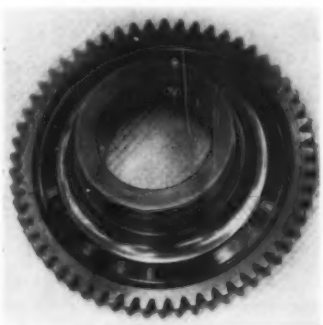
Brass die castings are corrosion resistant, have good bearing properties, and can be soldered and plated. Rather small in size – about 5 lb. is maximum – brass die castings require wider dimensional tolerances than alloys with lower melting points; the minimum section thickness is about 0.050 in.

What Metal Shall I Use . . .

for Bearings To Be Employed at Elevated Temperatures?

*By H. M. LAMPERT**

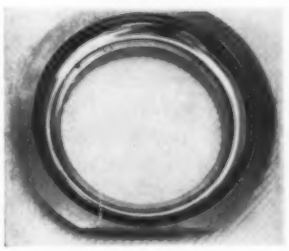
In selecting materials for high-temperature bearings, engineers must consider the type of environment and the lubricant as well as the maximum temperature that the bearing is to withstand. As of today, bearings can be fabricated for use up to 1200° F., and higher temperatures are expected in the future. (T7d, 1-66; SGA-c)



Thrust Bearing Inner Race With Integral Gear (M50)

BECAUSE OF THE CONTINUING DEMAND for greater power and increased efficiency, operating temperatures in all types of equipment have been constantly rising. This, in turn, has resulted in ever more severe requirements for materials used in parts which undergo sliding or rolling action such as gears, journals, rolling contact bearings and seals.

The problem is complex, since materials generally become chemically and metallurgically more active and mechanically less stable as temperatures increase; galling, seizure and premature failure often result. As a further complication, selection of materials for such parts is not only a function of the thermal environment, but of the chemical environment (lubricant), atmosphere (air, inert, vacuum), mechanical loading, and system requirements (thermal expansion, conductivity).



Thrust Bearing Outer Race (M50)

Roller Bearings (50) and Retainer (Iron-Silicon Bronze)

Ball Bearings (M50) and Retainer (Iron-Silicon Bronze)

Some Basic Concepts

Each new application involving a different set of operating parameters stimulates a re-examination of the basic concepts of wear and friction. Most workers in the field today con-

*Functional Engineer, Materials and Processes Engineering, Missile and Space Vehicle Dept., General Electric Co., Philadelphia.

M P **Fact Sheet**

Sleeve Bearing Materials for Elevated-Temperature Applications

Material	Composition, %	Max. Temp.	"PV" Factor*	Shaft	Atmosphere	Fluid†	Hardness
Leaded bronze	80 Cu, 10 Sn, 10 Pb	350° F.	100,000	Hardened steel	Air	1	157 Bhn.
Iron-silicon bronze	92.5 Cu, 3 Si, 3 Zn, 1.5 Fe	400	60,000	Hardened steel	Air	1	130
		500	40,000	Cr-plated steel	Air	2,3	–
Beryllium copper	96.9 Cu, 2.5 Co, 0.6 Be	400	80,000	Hardened steel	Air	1	100
		550	60,000	Cr-plated steel	Inert	2,3	–
Silver plate	100 Ag	400	40,000	Hardened or Cr-plated steel shafts can be used at both temperatures	Air	1	65
		600	30,000		Inert	2,3	–
Silver-lead plate	99.5 Ag, 0.5 Pb	450	45,000	Hardened or Cr-plated steel	Inert	2,3	100
Palladium alloy	35 Pd, 30 Ag, 14 Cu, 10 Pt, 10 Au, 1 Zn	450	40,000	Hardened or Cr-plated steel	Inert	2	23
Silver-palladium	90 Ag, 10 Pd	500	40,000	Cr-plated steel	Inert	2	67
		500	20,000	Hardened steel	Inert	2	–
"S" Monel	65 Ni, 27 Cu, 4 Si, 3 Fe, 1Mn	500	25,000	Hardened steel	Air	1,3	320
Coin silver	90 Ag, 10 Cu	500	60,000	Hardened Cr-plated steel	Inert	2	118
		550	40,000	Cr-plated steel only	Inert	3	–
Silver-manganese nickel	99.6 Ag, 0.2 Mg, 0.2 Ni	600	60,000	Hardened or Cr-plated steel	Inert	2,3	200
Silver-tungsten-graphite	73 W, 25 Ag, 2 C	650	80,000	Hardened steel	Air or inert	1,2,3	173
Graphite-silver	90 C, 10 Ag	650	50,000	Hardened or Cr-plated steel	Air or inert	1,2,3	–
Graphite	100 C	800	50,000	Cr-plated steel	Air or inert	1,2,3	–

*The "PV" factor is equal to the load (in psi.) x velocity (in ft. per min.).

†Fluids: (1) Di-2- ethylhexyl sebacate ester; –65 to 300° F.; can be used with any metal.
(2) Trimethylolpropane ester; –65 to 400° F.; cannot be used with lead or magnesium.
(3) Hexa(2-ethyl butoxy)disiloxane; –65 to 600° F.; cannot be used with lead, magnesium, copper or aluminum above 400° F.

sider wear and friction to be basically a welding phenomenon which is profoundly affected by chemical reactions on surfaces. Several factors must be considered when developing, evaluating, and selecting materials for advanced applications. Among these are:

• Metallurgical phase relationships – The less alloying tendency that exists between bearing and shaft materials (iron and silver, for instance) the less tendency there is for them to weld, gall and seize.

• Crystal structures – A lamellar structure in a solid lubricant such as graphite or molybdenum disulfide produces low frictional coefficients.

• Thermal properties – A good conductor with a high heat capacity such as copper can carry heat away from the mating surfaces; this reduces the tendency to weld.

• Chemical or surface properties – An alloy having a tendency to form an adherent film, such as silicon-iron bronze or "S" Monel in oxidizing atmospheres, restricts the area in which detrimental surface welding can occur.

• Mechanical properties – Materials having low shear strengths such as lead and tin shear easily even when surface welding occurs; this is an advantage.

Fluids Are Important

The type of working fluid (lubricant) to be used has a profound effect on the selection of materials for bearings. As an added complication in fluid selection, design and system re-

	Characteristics and Applications
	Value rated on 0.030-in. coating on steel backing (bushing application). This material is widely used for bearing cages or separators.
	Good for high-speed applications.
	"PV" values for silver and silver-lead coats are for 0.020 to 0.030-in. plates on steel backing. Thinner coats carry higher loads.
	Silver-lead alloys contain 0.5 to 2.0% Pb.
	Palladium and silver-palladium alloys are used for contact points in relays and other electrical equipment.
	"PV" ratings are for 0.050 to 0.060-in. coatings brazed to steel backs.
	These alloys are used for bearing retainers and separators. Because it contains copper, "S" Monel cannot be used with fluids that attack copper. With 2 to 10% Ag added, these alloys have better machinability and frictional properties.
	This alloy can be hardened; it is useful for applications between those for silver and silver-tungsten sintered alloys.
	Variations on standard electrical contact materials, these alloys consist of a porous mixture of tungsten, tungsten carbide, and graphite.
	Used in high-speed, low-load, continuous contact applications (such as rotating shaft seals) mated with chromium-plated or nitrided parts.

quirements often place primary emphasis on such fluid properties as hydrolytic, thermal and shear stability, viscosity-temperature characteristics and bulk modulus. Under these circumstances, lubricity, or lubricating power, may be a secondary consideration.

Wider operating temperature ranges require the use of synthetic fluids as opposed to petroleum-based lubricants. Three important lubricants, di-2-ethylhexyl sebacate ester, trimethylolpropane ester, and hexa(2-ethyl butoxy) disiloxane are listed in the M-P Fact Sheet on this page. Aside from these, three others are in common use. These are: mineral oils (−40 to 700° F.), polyphenyl ethers (20 to 800° F.), and liquid metals (0 to 1400° F.). As an example of the latter, an NaK eutectic can be used for lubrication at high temperatures.

Each of the first three liquids contain various additives to improve properties. In frictional applications, the one of primary interest is the EP, or extreme pressure, additive. Its function is to attack spots of incipient seizure (hot spots) chemically to form a protective film.

Incidentally, many of the fluids, in particular the first two listed, deteriorate with time to form acid products which may result in excessive corrosion. In line with this, it is important to remember that the working fluid can have a chemical effect on the bearing material selected. Consequently, preliminary corrosion tests are often needed. For these tests, metal disks are exposed for 72 hr. in test tubes containing the fluid and through which air or nitrogen is bubbled. The extent and nature of corrosive attack is determined, and, based on prior correlation with service tests, an arbitrary temperature limit is established. The Fact Sheet contains information on the limits of lead, copper, silver, steel, magnesium, aluminum, titanium, cast iron, and chromium based on bench and service tests.

Applying the Right Alloy

The application of materials to bearings is dependent on the nature of contact, the atmosphere and environment, and the lubricant. From the standpoint of surface cooling and film repair, it is important to know whether bearing contact is intermittent or continuous. For example, a journal bearing normally operates with the bearing in continuous contact and the shaft in intermittent contact. That is, as the shaft rotates, it presents a continuously changing surface to the same surface on the bearing. Conversely, a rotating shaft seal operates with both surfaces in continuous contact, and gears operate with both surfaces in intermittent contact.

To obtain the results shown in the Fact Sheet, bench tests were run on a Hohman Model A-6 test rig. In this machine, two rub shoes are force-loaded against a rotating test ring that is restrained by a strain-gage ring. The coefficient of friction can then be measured as a function of atmosphere, load, speed, temperature and fluid. Figure 1 shows some typical results obtained on leaded bronze operated as a bearing in a chlorinated silicone fluid. The upper curve in this figure is for straight cast material and the lower curve is for cast material on a steel back. Due to the thickness *(Continued on p. 152)*

What Tool Steel Shall I Use . . .

for Applications in Structures and Components?

Engineers are taking a closer look at tool steels for nontooling applications. Already used in aircraft structures, fasteners, bearings and wear parts, their wide range of properties – high hot hardness, strength, wear resistance, toughness – has made them valuable as primary engineering materials. (A-general; TS, SGB-s, 17-57)

THE USE OF MODIFIED H11 HOT WORK die steel for structural parts in aircraft has dramatized the growing importance of tool steels for structures and components. But there are many less glamorous applications where tool steels are solving tough problems outside their usual area of application. For example, you'll find tool steels being employed for bearings, in components for special printing machinery, in food and shredding machinery, and in wear parts.

Tool steels have been employed in nontooling applications because one or more of the properties which set them apart from the family of regular steels met a specific design requirement. No one steel possesses all of the special characteristics – high hardenability, very high strength at elevated temperature, toughness, excellent wear resistance, ability to air harden with a minimum of distortion, hot hardness and some stainless qualities – but a number exhibit combinations which make them highly useful as engineering materials. From the straight carbon, water-hardening steels, containing practically no alloying elements, to the very highly alloyed hot work and high speed steels, there is a wide range of steels designed to provide many combinations of properties.

H11 for High Strength

As an example, we can consider the outstanding characteristics of modified H11, a 5% Cr hot work tool steel (see the M-P Fact Sheet on p. 106). It achieves tensile strengths of 220,000 to 310,000 psi. at room temperature, it is ductile (14 to 15% reduction in area can be expected at 280,000 to 300,000 psi. in large sections of consumable-electrode, vacuum-arc melted material), it is air hardenable and is stable after heat treatment. Maximum strength is attained through secondary hardening by tempering at 1000 to 1100° F. Because the secondary hardness phenomenon occurs at high tempering temperature, H11 retains its strength at elevated temperatures. Multiple tempering at 1000 to 1100° F. also permits maximum stress relief and bake out of hydrogen without loss of strength and leaves the microstructure essentially free of retained austenite. Consequently, there can be no stress-induced transformation of retained austenite to fresh, brittle martensite, a disadvantage of low-alloy, ultrahigh strength steels. This is particularly important in parts subject to fatigue loads which fail quickly if transformations occur.

Modified H11, like other tool steels, requires a considerably shorter heat treating cycle than high-temperature alloys, and, therefore, it offers savings in production costs for parts which must operate up to 1000° F. In addition, it is easier to fabricate, either hot or cold, than the precipitation-hardening alloys.

Modified H11 is generally melted by the electric arc process which provides an entirely satisfactory product for many applications. But in the never-ending quest for higher strength-to-weight ratios with adequate ductility, aircraft and missile designers are now specifying consumable-electrode, vacuum-arc melted material although electric-arc melted H11 has proved satisfactory in many applica-

tions. When techniques in which the electrode is melted in a vacuum or under a protective flux (the Hopkins process) are used, less reduction to obtain uniform properties is necessary during processing from ingot to billet. Fatigue strength of H11, the highest of any air-melted steel, is also improved.

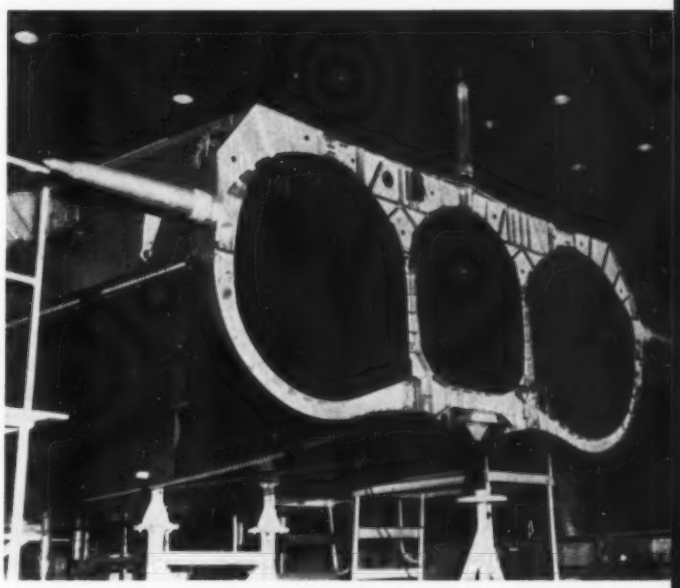
Like low-alloy steels, H11 does not have high resistance to corrosion and oxidation. For protection, a number of surface coatings are available for most operating requirements including marine environments. Various paints, enamels and organic finishes are used extensively. Either cadmium, nickel, or chromium may be deposited electrolytically from special low-hydrogen baths. For service up to 900 to 1000° F., silicone-aluminum paint, nickel-zinc plating (A.M.S. 2417) or diffused nickel-cadmium plating (A.M.S. 2416) are satisfactory. Other treatments include diffused aluminum coatings which protect H11 parts above 1500° F., diffused chromium for resistance to corrosion and wear, and nitriding which provides surface hardnesses as high as those of the aluminum nitriding steels.

Where H11 Is Used

Some of the most recent applications for modified H11 heat treated to strength levels above 280,000 psi. are found in the A3J Vigilante, built by North American Aviation, Inc. This aircraft has 190 5% Cr steel parts in highly stressed locations such as the 14-ft. carry-through tail structure. To fabricate this section, closed-die forgings were welded together. These machined forgings have sections ranging from 1/16 to 5 in. thick and are air hardened from controlled-atmosphere furnaces with a minimum of distortion. They require little or no finish machining after heat treatment.

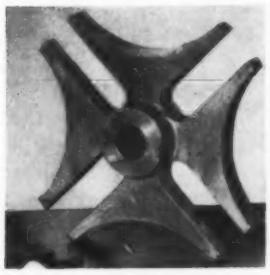
Other critically stressed components fabricated from modified H11 for aircraft such as the B70 and B58 are landing gear, arresting and catapult gear, hydraulic components and elevon hinges. In some instances, the operating temperatures range from 640 to 800° F. Extensive testing has shown that the steel maintains strength, ductility, and a stable structure to 1000° F. In addition, engineers at North American Aviation have reported that a notch strength of over 400,000 psi. (notch strength ratio, 1.4) is retained down to −140° F. with a relatively sharp notch (K=6.25).

In the missile field, Pratt & Whitney Aircraft has successfully manufactured and tested full-scale rocket cases heat treated to a uniaxial



H11 Aircraft Structure

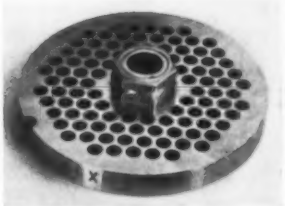
Mandrel for Wire Stitcher (A6)



A4 Machine Part

S2 Mower Blade

H11 Fasteners



D2 Meat Chopper Plates

Tool Steels for Application in Structures and Components

Type	Composition	Outstanding Properties	Present and Potential Applications
H11 (modified)	0.40 C, 5.00 Cr, 0.50 V, 1.30 Mo (typical analysis)	Ductility and ultrahigh strength (to about 300,000 psi.). Stable up to 1000° F. Deep air hardening. Low distortion in heat treatment. Freedom from retained austenite insures stability in hardened condition	Aircraft structurals, landing gear, fasteners, missile cases, fuel injection nozzles, valves and inserts, springs for intermediate temperatures (to about 800° F.), machine tool spindles, nitrided gears and shafts
H13	0.35 C, 5.00 Cr, 1.00 V, 1.50 Mo, and alloy sulfides	Machines readily in hardened (Rc 42 to 46) state if sulfides are added	Machine tool components requiring strength and rigidity
H21	0.35 C, 3.50 Cr, 9.00 W	Fair wear resistance, high hot hardness up to 1100° F. Good compressive strength, oil or air hardening	High-temperature springs
M50*	0.81 C, 0.25 Mn, 0.30 Si, 4.10 Cr, 1.00 V, 4.25 Mo (typical analysis)	Good wear resistance, high hot hardness	High-temperature springs, parts for hydraulic pumps, races and rollers for roller bearings, valves and inserts, ball bearings
M1	0.80 C, 4.00 Cr, 1.00 V, 1.50 W, 8.00 Mo	General-purpose high speed steels, each possessing high hot hardness, and good wear resistance	High-temperature gears, bearings† and springs; vanes, pistons, bodies for hydraulic pumps; cams, food chopper blades
M2	0.80 C, 4.00 Cr, 2.00 V, 6.00 W, 5.00 Mo		
M10	0.85 C, 4.00 Cr, 2.00 V, 8.00 Mo		
T1	0.70 C, 4.00 Cr, 1.00 V, 18.00 W		
M3	1.00 or 1.20 C, 4.00 Cr, 2.70 or 3.00 V, 6.00 W, 5.00 Mo	Hot hardness and wear resistance superior to those of T1, M1, M2, M10	Same uses as T1, M1, M2, M10. Principal application has been in specialized high-temperature bearings†
M4	1.30 C, 4.00 Cr, 4.00 V, 5.50 W 4.50 Mo		
T5	0.80 C, 4.00 Cr, 2.00 V, 18.00 W, 8.00 Co		
T15	1.50 C, 4.00 Cr, 5.00 V, 12.00 W, 5.00 Co		
A2	1.00 C, 5.00 Cr, 1.00 Mo	Air hardening, very low distortion when heat treated. Wear resistance at room temperature ranges from good to superior depending on carbon and alloy content. Wear resistance generally improves (with some sacrifice in impact strength) as carbon content increases	Fuel injection nozzles, plungers for diesel fuel injection pumps, and cam followers, profile bars and spindles, wear plates and slideways; seam rollers, gages, brick mold liners. Wear parts in machine tools; food chopper and business machine parts, worm-type pump rotors. Parts for hydraulic systems
A4	1.00 C, 2.00 Mn, 1.00 Cr, 1.00 Mo		
A6	0.70 C, 2.00 Mn, 1.00 Cr, 1.00 Mo		
A7	2.25 C, 5.25 Cr, 4.75 V, 1.00 W (opt.), 1.00 Mo		
A8	0.55 C, 0.30 Mn, 0.95 Si, 5.00 Cr, 1.20 W, 1.20 Mo		
A9	0.50 C, 5.00 Cr, 1.00 V, 1.40 Mo, 1.50 Ni		
D2	1.50 C, 12.00 Cr, 1.00 Mo		
D4	2.25 C, 12.00 Cr, 1.00 Mo		
D5	1.50 C, 12.00 Cr, 1.00 Mo, 3.00 Co		
D7	2.25 C, 12.00 Cr, 4.00 V, 1.00 Mo		
S1	0.50 C, 1.50 Cr, 2.50 W	Shock resisting, provide good balance of hardness and excellent toughness, low distortion in heat treatment, excellent stability in hardened condition	Power tool components, piercing projectiles for oil well casings
S2	0.50 C, 1.00 Si, 0.50 Mo		
S4	0.55 C, 0.80 Mn, 2.00 Si		
S5	0.55 C, 0.80 Mn, 2.00 Si, 0.40 Mo		
S7	0.55 C, 0.70 Mn, 0.25 Si, 3.25 Cr, 1.40 Mo		
W1	0.60–1.40 C	Harden to form wear-resistant case around tough core	Pistons in pneumatic tools, pins and shafts for motors, parts for typesetting equipment, blades for hair clippers, shuttles for textile machinery
W2	0.60–1.40 C, 0.25 V		
O2	0.90 C, 1.60 Mn	Good combination of dimensional stability, wear resistance and machinability	Pistons for hydraulic presses
L6	0.70 C, 0.75 Cr, 1.50 Ni, 0.25 Mo, (opt.)	Better dimensional stability than water hardening grades. Very good toughness	Ratchets, gears, load cells

*Not an AISI tool steel designation.

†For more detailed information on materials for high-temperature bearings, see p. 101.

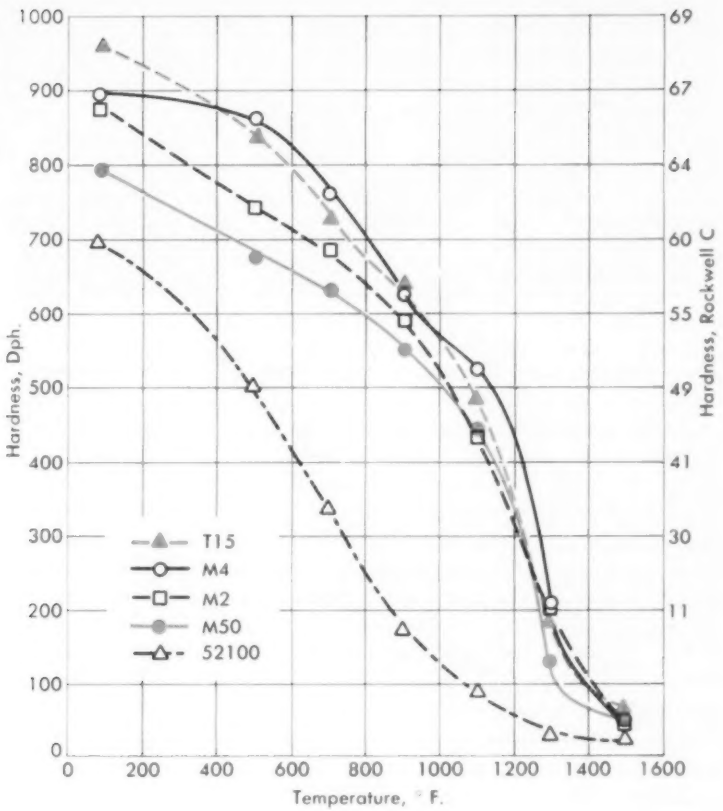


Fig. 1 – Hot Hardness of Several Tool Steels Used for Bearings. High hot hardness and excellent wear resistance permit the tool steels to be used up to at least 700° F.

yield strength of 240,000 psi., corresponding to the 290,000 to 300,000 psi. ultimate tensile strength. Longitudinal welds were eliminated by forging rings from pierced steel billets and then flow-turning them to final size.

Another interesting application is the use of 5% Cr steels for a component weighing about 9000 lb. in a massive wind tunnel at McDonnell Aircraft. Advantage was taken of the deep air hardenability of H11 to produce a strength level of 220,000 psi. through a 12-in. section.

Various types of ultrahigh strength fasteners are also being fabricated from 5% Cr steels. Bolts are commonly used at strength levels of 220,000 psi. and 260,000 psi., with some experimental designs at 300,000 psi. In addition to high notch strength and stability at elevated temperature, the fasteners exhibit excellent fatigue resistance, which is about 35% higher than A.I.S.I. 4340 at the same strength level.

Another tool steel listed in the Fact Sheet, H13 (prehardened), was originally developed as a prehardened hot work die steel. It has, however, found considerable nontooling applications, primarily as machine tool components.

Tool Steels for High-Temperature Bearings

Another large area for application of tool steels in nontooling jobs is in bearings, particularly in bearings for jet engines. Here the need is for materials which retain a hardness of at least Rockwell C-58 at high operating temperature for at least 1000 hr., a high degree of dimensional stability, good resistance to oxidation and corrosion in operating environments, high compressive strength, and high fatigue and wear resistance.

High speed steels and hardenable stainless steels (Type 440C and its variations) have in the past few years received considerable attention because the most commonly used bearing steel, S.A.E. 52100, begins to lose its dimensional stability and hardness at about 450° F., which is near the operating temperature now encountered in jet engines. With the need for higher and higher operating temperatures has come a growing trend toward use of the high speed steels. Figure 1 gives an indication of where they fit in the bearing picture: it shows that several tool steels have no difficulty retain-

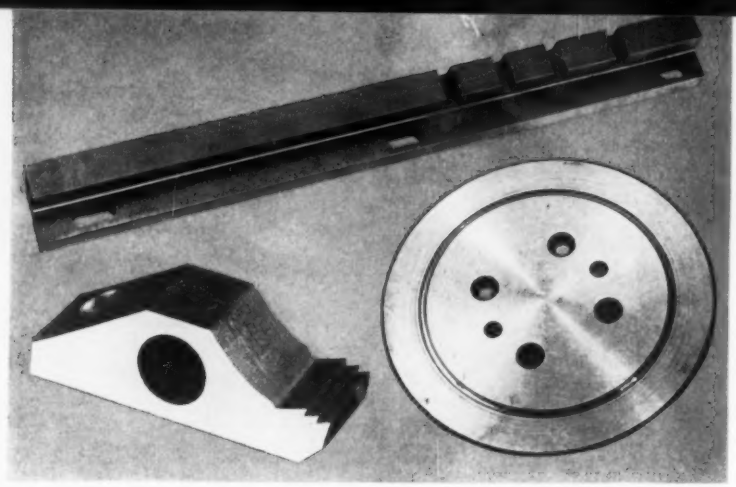


Fig. 2 – Precision Parts of A.I.S.I. A6 Tool Steel. Top: selector lever in a comparator; left: feed pawl for a shaper; right: wear plate on can-making machines. Low distortion of A6 and other air-hardening tool steels often means that parts require little or no finishing after heat treatment.

ing a hardness of Rockwell C-58 at least to 700° F.

Along with this excellent hot hardness goes excellent wear resistance, a combination of properties which accounts for the use of these steels for bearings operating at moderately high temperatures; the limit presently is about 700 to 800° F. because the resistance to oxidation is poor unless the bearing is surrounded by an inert environment.

For bearings, most demand has been for A.I.S.I. grades T1, M1, M2, and M10 and for the widely available nonstandard, M50. Although used in both the air-melted and vacuum-melted condition, steel melted by the latter technique has the advantage of better microcleanliness and improved fatigue life.

High speed steels such as T15 and M4 also show considerable promise as bearing materials. Containing 4 to 5% V and higher carbon contents than either M2 or M50, these grades have a greater amount of extremely hard vanadium carbide and are thus the most wear resistant of the fabricable, heat treatable materials. Improved corrosion resistance can be had by departing from the standard analyses.

Increasing the silicon and chromium contents, for example, raises the corrosion resistance at elevated temperatures until it is close to that of the high-chromium stainless steels. In addition, modified hardenable stainless steel (modified Type 440C) has found applications where corrosion resistance is needed in bearings. It lacks the hot hardness of the high speed steels, but its wear resistance can be improved by increasing the carbon content and adding vanadium.

High Fatigue Strength and Wear Resistance

As indicated in the Fact Sheet, another important segment in the nontooling applications for tool steels lies in high-temperature springs. These springs are found in safety valves, steam turbines, nuclear power systems and turbine engines. Most extensively used at elevated temperatures are H21 and T1, both of which have excellent fatigue strength and minimum relaxation in addition to good hot strength because of the secondary hardening treatment above 1000° F. Although their resistance to oxidation and corrosion is limited, H21 and T1 are, nevertheless, satisfactory in many applications where temperatures do not exceed 700° F.

These steels can be either hot or cold coiled. To increase the proportional limit, some springs are heat treated and then cold drawn and tempered before being coiled cold. Generally springs made from tool steels are put into service at a hardness of Rockwell C-48 to 50.

Wear resistance is also important in other parts in addition to bearings. With the development of wear-resistant grades such as D7 and A7, brick manufacturers have found that these alloys increase the life of brick mold liners. The experience of one brick manufacturer has been that A7 gives 20 times longer life than carburized and hardened steels.

Other air-hardening medium-alloy steels such as A2 and high-carbon, high-chromium steels, D2 and D5, make excellent wear parts and cams for machine tools. These grades are generally used where high hardness at room temperature, rather than at elevated temperature, is important. In food choppers, for example, D2 has proved an excellent material for blades. Although M2 has been used in the same application, D2 has an advantage since, in addition to wear resistance, its high chromium content gives it some stainless qualities.

Low Distortion During Heat Treatment

Special printing machinery and shredding machinery have parts which are subjected to high wear and which are also complex in de-

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sign. Where distortion becomes a problem when case-hardening steels are employed, then tool steels such as A2, A6 and D2 can be used to advantage. In the hardened condition, they often need no additional surface treatment and rejections because of distortion during heat treatment are reduced. Another good example which demonstrates the wear resistance and toughness of A2 is its use in the upper body of oil field pump valves. This part must also resist the erosion of sand and gravel.

For parts where the primary requirement is toughness, design engineers should consider the shock-resisting steels. Grades such as S1 and S5 have been used for shafts and gears in small power tools, cutter heads and clutch collars. Water-hardening grades such as W1 and W2, actually straight-carbon steels with precisely controlled hardenability, are capable of attaining high hardness and good toughness because they form a hard case around a tough core. Stability during heat treatment and strength at elevated temperature are not characteristics of these grades, but the favorable combination of toughness and hardness gives them long life in parts for pneumatic tools.

Future Advances in High-Strength Applications

All of the applications which have been described here point out that tool steels are establishing themselves as important materials for structures and components. But many design engineers have not yet realized the potential offered by these steels, most often because of the lack of data on mechanical properties. This situation is changing as shown by the extensive work which has been done in the bearing field and with H11 and its modifications.

As the demand for higher and higher strength continues, tool steels can be expected to assume a more important role where strength-to-weight ratio and notch toughness are important. What type of steel compositions are expected to achieve extremely high strength levels of perhaps 350,000 to 450,000 psi? Studies in alloy development over the years provide a good indicator. It has been demonstrated, for example, that highly alloyed high speed steels such as T1 and M2 develop the highest strength available in any existing material; they show a proportional increase in strength with hardness up to a yield strength of about 390,000 psi. Unfortunately, high speed steels achieve this strength at a sacrifice in ductility that would necessitate drastic changes in structural design criteria for notches, stress raisers and shock resistance.

But the results of research indicate clearly that higher strength levels will necessitate higher alloy contents. Furthermore, a mechanism like secondary hardening, which provides maximum stress relief, and transformation of retained austenite by multiple tempering above 950° F. assume increasing importance at these strength levels. Vacuum melting also appears essential.

One of the newest techniques leading to higher strength steels is Ausforming, or warm working of austenite in the 600 to 1200° F. region following conventional austenitizing (see *Metal Progress*, September 1961, p. 68). This process results in a fully hardened part after the warm working operation. It is, therefore, currently limited to parts in which over 25% deformation can be accomplished within the warm working range rather than during heat treatment, with no subsequent welding, forming or extensive metal removal operations permitted. However, it does hold promise for certain designs, and the potential for obtaining strength without loss in ductility is encouraging. The capability of the technique is demonstrated by tests made at the Ford Scientific Laboratory where a modified H11 (0.35% C), Ausformed and then tempered at 700° F., reached a tensile strength of 430,000 psi., and a yield strength of 415,000 psi.; elongation and reduction in area were 4.5 and 24%, respectively.

What Metal Shall I Use . . .

for Fabrication of Cryogenic Vessels and Equipment?

*By GEORGE H. ZENNER**

The rapid growth of the cryogenic industry has focused much attention on metals to use in fabricating vessels and equipment for low-temperature service. Techniques for selection and methods for welding metals for industrial cryogenic applications are presented. (K-general, Q23r, T26q, 1-67, 1-54; SGB-r)

THE EFFECT OF LOW TEMPERATURE on toughness is probably the most important consideration in selecting metals for cryogenic applications. A number of failures of vessels and structures have been due to inadequate attention to this factor. Steels particularly have "notch sensitivity", whereby the metal at low temperature behaves in a brittle manner in the presence of a notch, although in the absence of such localized stress raisers, it exhibits ductility.

The notched-bar impact test has been developed to measure the toughness of metals at low temperatures. The important factor here is the use of a notched specimen, and the specific method of test, by impact, is a matter of convenience and has no particular relationship to the conditions of service for the metal. The Charpy keyhole specimen has been the standard for many years; however, today the V-notch is being employed with increasing frequency. A notched-tensile test is also being used to some extent to secure design data and to avoid some of the objections to the impact test. The correlation of toughness data with performance of a fabricated vessel, however, is still uncertain.

What Is Adequate Toughness?

It has been reasonably well established that a minimum of 15 ft-lb. at low temperature for the standard Charpy keyhole or V-notch specimen assures adequate toughness in steels used for pressure vessels. The impact strength is roughly a product of the tensile strength of the metal and the deformation of a small volume of metal in the vicinity of the notch. Thus, it is erroneous to expect high impact values from low-strength metals, such as soft aluminum. Conversely, it is justifiable to expect higher impact values for metals with unusually high tensile strength. An examination of the fracture is often a useful criterion in evaluating impact test data†.

The common nonferrous metals – copper, aluminum, nickel, and their alloys – generally do not undergo any loss in toughness at low temperatures. The A.S.M.E. Code rules, therefore, do not require impact tests on approved alloys of these metals or their welds down to −325° F. The region below −325° F., however, has not been adequately investigated to permit such a generalization. The M-P Fact Sheet on p. 114 includes impact data for plate

*Assistant Manager, Engineering Laboratory, Linde Co., Div. of Union Carbide Corp., Tonawanda, N.Y. The author expresses his gratitude to C. M. Heath, metallurgy consultant for the Linde Co., whose knowledge and experience have provided much of the information for this article.

†Data on a wide range of metals is given in Monograph 13, "Mechanical Properties of Structural Materials at Low Temperatures", and other publications of the U. S. Department of Commerce, National Bureau of Standards, Washington, D.C.

materials in the annealed condition at 70° F. and at a specified low temperature.

Thermal Conductivity

Heat conduction (heat leak) through piping and supports can be a serious problem in many low-temperature installations. The ratio of strength-to-conductivity is an index of the relative suitability of different metals for cryogenic service. This is a most important factor, especially now since liquid hydrogen (boiling point: −423° F.) and super insulations are coming into more widespread use because heat conduction through metal supports becomes a major source of heat leak. Figure 1 shows super insulation between the inner and outer shell of a liquid hydrogen tank car.

Plastics and other nonmetals are sometimes employed for supports since their strength-to-conductivity ratio is superior to that of metals. Thermal conductivity may change rapidly with temperature, so the coefficients given in the Fact Sheet should not be used for other ranges.

It is fortunate that austenitic stainless steels and certain copper alloys (these are among the most widely used metals for cryogenic purposes) also have very low values of thermal conductivity. Special alloys (the Hastelloys are good examples) which have unusually high strength-to-conductivity ratios are also available. In a few instances, such as for extended surfaces on heat exchangers, high thermal conductivity is desired. For this application, copper and aluminum are useful.

Thermal Expansion and Contraction

A liquid container, 36 ft. long, made of 18-8 stainless steel, will contract 1¼ in. when cooled from ambient temperature to the boiling point of liquid hydrogen (−423° F.). Aluminum structures change even more. Such large dimensional changes occurring in the confined spaces of most cryogenic structures require special attention to the stresses which result. This expansion-contraction problem is particularly significant in long pipelines that are provided with a rigid vacuum jacket for insulation. Here the liquid line is sometimes made of Invar to minimize the problem. In most instances, there is no further significant change in total contraction below −320° F. (liquid nitrogen).

Metals for Cryogenic Vessels

The need for large pressure vessels for use at pressures of 200 psi. or higher at ultralow

Welding Aluminum Tank for Liquid Oxygen

Stainless Vessel for Liquid Hydrogen

Baffles in Liquid-Hydrogen Tank

Piping for Liquid Hydrogen

Welding 9% Ni Tank for Liquid Oxygen

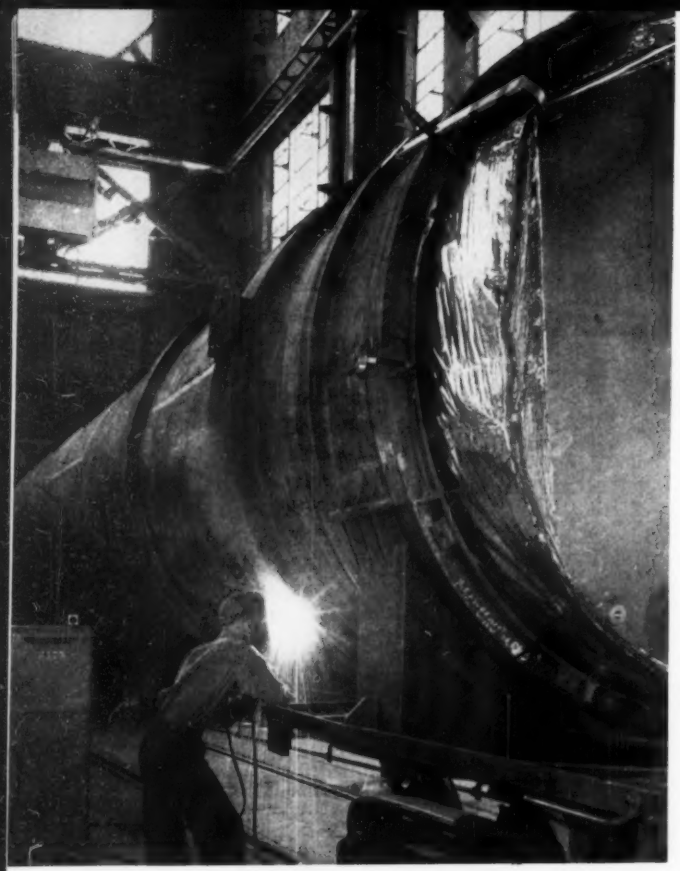


Fig. 1 – Super Insulation Goes Between Inner Stainless Steel Tank and Outer Carbon Steel Shell of 28,000 Gal. Liquid Hydrogen Tank Car. Insulation consists of alternate layers of aluminum foil and thin fiberglas-plastic sheeting

temperature requires strong, weldable alloys suitable for cryogenic service. Numerous alloy steels in the quenched and tempered condition are tough at very low temperatures, but welding upsets the low-temperature properties in the weld area of many of them. Furthermore, the deposited weld metal almost always has poorer low-temperature properties than the base metal.

Many nonferrous alloys which have excellent tensile strength and high yield point in the cold-rolled condition become soft and weakened in the weld area. High strength and toughness in the welded joint for these alloys depend primarily on alloy content of both the base plate and weld deposit.

The M-P Fact Sheet lists the metals commonly used for cryogenic service. Although the term "cryogenic" usually refers to temperatures below about −200° F., the list also includes a few steels which are only suitable at appreciably higher "low" temperatures.

The steels listed are those included in SA-300 of the A.S.M.E. Code for Unfired Pressure Vessels. In numerous instances a welding rod of a composition different from that of the base metal is used to obtain satisfactory properties in the deposited weld metal. The Code provides dependable rules for the selection of a suitable metal and welding procedure by establishing checks on the base metal, the welding process, and the operator. The tensile properties given for 70° F. are usually Code specification values for annealed plate and they are appreciably lower than many test results. The strength at low temperature is similarly on the conservative side.

Carbon Steels

Fine-grained carbon steels, SA-201 and 212, are suitable down to −50° F. (The fine grain frequently is obtained by ladle addition of aluminum.) It is also helpful to have a manganese-to-carbon ratio of about 4:1, and for this reason, the manganese content is increased slightly. Also, because of this, only Grade A – normally of lower carbon content – is shown in the Fact Sheet, although Grade B materials permit higher design stresses.

Impact specimens taken transverse to the direction of rolling may show much lower values than specimens taken lengthwise. This problem can be avoided by having the plates cross-rolled. The welding rods employed for these steels are A.W.S. specification, low-hydrogen electrodes intended for low-temperature use.

Wires of cold-drawn carbon steel have been used in prestressed concrete tanks for storing liquid oxygen at −297° F. These wires have displayed remarkable toughness when notched and bent at −320° F. The notched portion remained straight and separated from the unnotched bent portion in the same manner as a notched branch of a green tree when it is bent. These wires are considered suitable for low-temperature service.

Low-Alloy Steels

Low-alloy steels shown on the Fact Sheet have properties suitable for specific low-temperature use. Fine grain is also important for these steels and they may be subject to directional properties. At present, none of them is approved for operation below −320° F

Welding of 9% Ni steel is best accomplished with an austenitic electrode, preferably Inco "A". Considerable trouble has been encountered from arc-blow during welding caused by residual magnetism in the steel plate. Thus,

extra precautions in handling the material have been necessary. The Code now requires stress relief of welded vessels of 9% Ni steel, but efforts are under way to eliminate this requirement. Stress relief can have pronounced beneficial or deleterious effects on the low-temperature properties of welded carbon and low-alloy steels. It must be investigated for each combination of plate and weld metal.

Austenitic Stainless Steels

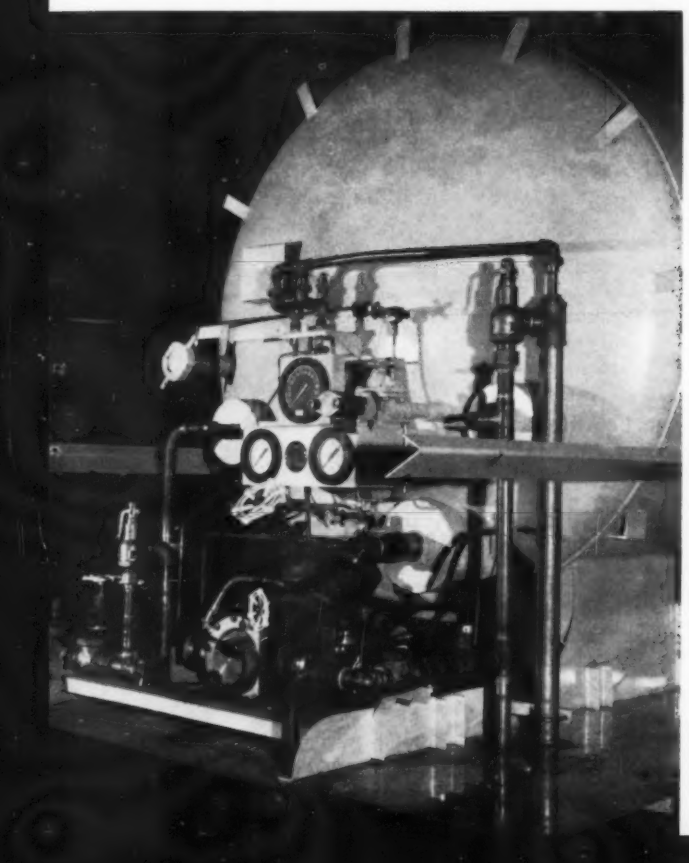
These alloys are widely used for vessels operating at −250° F. and below. They are tough, readily welded, and possess high strength and low thermal conductivity. This combination of properties makes them almost ideal for cryogenic use. The usual precautions against prolonged heating of these alloys in the 900 to 1600° F. range should be observed. Such heating affects low-temperature toughness adversely, especially in the weld.

Type 304 stainless has become the most popular of the group where weldability and toughness at low temperature are required. Type 347 has somewhat lower toughness in the weld zone than Type 304. The other austenitic stainless alloys are either more expensive or have special properties which limit their application. Type 301, for example, heavily cold rolled to provide high strength, is used extensively in thin sections to fabricate cryogenic propellant tanks in missiles (see *Metal Progress*, November 1959, p. 67).

Impact tests are required by the Code on the base metal and weld metal for all of these stainless steels when the service temperature is below −325° F. These tests are not required on the base metal for Type 304 and several other alloys if used above −325° F. A welding rod of higher alloy content than the base metal is generally employed, and carbon content should be kept low.

The A.I.S.I. type 200 alloys, having 17% Cr, 9 to 10% Mn, and 4 to 5% Ni, have recently been introduced in an effort to provide a less costly material for cryogenic vessels. Thus far, the properties of Types 201 and 202 appear to be uncertain at −320° F. Type 204 is probably satisfactory, but it is not readily available.

Fig. 2 – The Use of a Variety of Metals in Cryogenic Equipment Is Illustrated by Components of This Liquid Oxygen Truck (200,000 Cu.Ft. Capacity). The liquid-carrying inner tank is stainless, with a carbon steel outer casing. Valves are brass, bronze and cast iron. Piping is copper (Everdur), while the pump (lower left) is Meehanite cast iron, plated with cadmium. The operating compartment floor is aluminum



Copper and Copper-Base Alloys

Copper was one of the first metals to be employed for low-temperature service, and it is still an excellent choice where it is suitable. The copper-silicon alloy, SB-96 (especially Grade A-8, 96% Cu, 3¼% Si, ¾% Mn), has been used extensively where weldability and strength are desired.

Copper alloys of the solid-solution type appear to retain their toughness at temperatures approaching absolute zero, although the region below −325° F. has not been fully investigated, particularly for welded materials. The thermal conductivity of pure copper is extremely high, but, on the other hand, for the copper-silicon alloys it is quite low. The relatively high cost and low strength of copper and its alloys have, however, caused a decline in its use in recent years in favor of 9% Ni steel, austenitic stainless steel, and aluminum alloys.

Copper alloys in the form of bronze or brass castings are widely used for valve bodies and fittings at low temperature, as illustrated by Fig. 2. If attached by hard solder or brazing, the alloy should be essentially lead-free to avoid porosity caused by the brazing operation. A wide variety of brasses is employed for various

Metals for Fabrication of Cryogenic Vessels and Equipment

	Metal	Nominal Composition, %	Normal Lowest Allowable Temp.,† ° F.	Tensile Strength at 70° F. Psi.	Tensile Strength at Low Temp. ° F.	Tensile Strength at Low Temp. Psi.	Impact Resistance‡ at 70° F. Ft-Lb.	Impact Resistance‡ at Low Temp. ° F.	Impact Resistance‡ at Low Temp. Ft-Lb.
Low-carbon steels									
SA–300*	SA–201 Grade A(a)	0.35 C max.	–50	55,000	–50	62,000	50	–50	15(min.)
	SA–212 Grade A(a)	1 Mn max.	–50	65,000	–50	72,000	45	–50	15(min.)
Low-alloy steels									
SA–300	SA–203 Grade A(a)	2.4 Ni	–75	65,000	–75	85,000	45-55	–75	20–35
	SA–203 Grade D(a)	3.5 Ni	–150	65,000	–150	85,000	40	–150	15–35
	SA–410 (a)	0.75 Cr, 0.75 Ni, 0.55 Cu, 0.15 Al	–150	60,000	–	–	60	–150	15–40
	SA–353 Grade A(b)	9 Ni	–320	90,000	–320	135,000	25-65	–320	15–35
Austenitic stainless steels									
SA–167	Type 301	17 Cr, 7 Ni	Not established	100,000	–320	260,000	(c)	(c)	(c)
	Type 303	18 Cr, 8 Ni plus S or Se	Not restricted	75,000	–320	220,000	80	–320	80
	Type 304	18 Cr, 8 Ni	Not restricted	75,000	–423	220,000	100	–320	80
	Type 305(k)	18 Cr, 11 Ni	Not restricted	75,000	–423	200,000	100	–320	80
	Type 309S	23 Cr, 13 Ni	Not restricted	75,000	–	–	–	–	–
	Type 310S	25 Cr, 20 Ni	Not restricted	75,000	–423	170,000	75	–320	60
	Type 316	17 Cr, 12 Ni, 3 Mo	Not restricted	75,000	–423	180,000	65	–423	50
	Type 321(l)	18 Cr, 8 Ni plus Ti	Not restricted	75,000	–423	180,000	70	–320	45
	Type 347(l)	18 Cr, 10 Ni plus Cb	Not restricted	75,000	–423	200,000	58	–320	53
Copper alloys									
	Copper (annealed)	–	Not restricted	20,000	–423	60,000	55(d)	–320	52(d)
	Copper-silicon SB–96 Grade A–8	96 Cu, 3.25 Si, 0.75 Mn	Not restricted	50,000	–320	80,000	65	–320	55
	Muntz metal (lead-free)	60 Cu, 40 Zn	Not restricted	50,000	–320	65,000	50(d)	–320	45(d)
Aluminum alloys									
	3003–0	1.25 Mn	Not restricted	14,000	–320	30,000	17(e)	–320	22(e)
	5052–0	2.5 Mg	Not restricted	25,000	–320	40,000	–	–	–
	5083–0	4.5 Mg, 0.7 Mn	Not restricted	40,000	–320	60,000	17(f)	–320	16(f)
	5086–0	4.0 Mg, 0.5 Mn	Not restricted	35,000	–320	52,000	16(g)	–320	16(g)
	5154–0	3.5 Mg	Not restricted	30,000	–320	45,000	16(g)	–320	16(g)
	5456–0	5.0 Mg, 0.75 Mn	Not restricted	42,000	–320	60,000	10.5(g)	–320	9.5(g)
High-nickel alloys									
	Monel	68 Ni, 32 Cu	Not restricted	70,000	–320	110,000	219(h)	–320	196(h)
	Invar	36.2 Ni, 63.8 Fe	Not established	60,000	–320	100,000	45	–320	37
Other metals									
	Titanium alloy C–120–AV	6 Al, 4 V	Not established	120,000	–320	200,000	20	–320	10
	Cast iron	3.2 C, 2.0 Si	Not established	20,000	–320	22,000	24(i)	–320	15(i)

* SA designations refer to Material Specifications in Section II of the ASME Boiler and Pressure Vessel Code.
† At allowable design stress.
‡ Charpy keyhole notch except where otherwise indicated.
§ Average 70° to –320° F.
(a) Available as sheet and plate; SA–333 or 334 for pipe or tubing. Grade to suit temperature.
(b) Available as sheet and plate; SA–312 for pipe or tubing.
(c) Toughness of thin sections established by notch-tensile tests.
(d) Charpy V notch.
(e) H 112 temper.
(f) H 113 temper.
(g) 7.5-mm. wide Charpy specimen.
(h) As rolled, Charpy V.
(i) 1.2-in. diam. cast bar, unnotched.
(j) Coefficient decreases with increased amounts of cold work.
(k) Used primarily for spun heads.
(l) Used for vessels requiring stress relief.

machined parts. These alloys suffer no deterioration at low temperatures, but they may present problems in welding.

Aluminum Alloys

Aluminum and its alloys have long been known to retain their toughness at low temperatures. Impact values are frequently below 15 ft-lb., but this is generally due to low strength and not to brittleness, as may be seen by inspection of the fracture. The development of inert-gas-shielded arc welding greatly improved our ability to weld aluminum and encouraged the introduction of alloys in the

Coefficient of Thermal Conductivity, § Btu./Hr./Ft., ° F.	Coefficient of Thermal Expansion, § In./In., ° F.	Weldability	
		Rating	Welding Electrode
35(to −50° F.)	–	Excellent Excellent	E–7015 or 7016
20(to −75° F.)	6.0×10^{-6}	Excellent	E–8015–C1 or E–8016–C1
18(to −150 °F.)	–	Excellent	E–8015–C2 or E–8016–C2
–	–	Excellent	E–8015–C2 or E–8016–C2
14	5.3×10^{-6}	Satisfactory if magnetism is avoided	Inco "A"
–	7.2×10^{-6}	Excellent	Special joint design
–	7.2×10^{-6}(est.)	Free machining type; normally not welded	
7.0	7.2×10^{-6}	Excellent	Type 309, 310 or 308 ELC
7.2	7.2×10^{-6}(est.)	Excellent	Type 309, 310 or 308 ELC
7.2	7.2×10^{-6}(est.)	Excellent	Type 309
7.35	7.2×10^{-6}	Good	Type 310
7.2	7.2×10^{-6}(est.)	Excellent	Type 310
7.2	7.2×10^{-6}	Good	Type 347
7.0	7.3×10^{-6}	Good	Type 347
250	7.85×10^{-6}	Fair	Copper
9.0	–	Good	Copper-silicon
–	–	Satisfactory	Copper-silicon
90	10.0×10^{-6}	Excellent	1100
70	–	Good	5052
–	10.4×10^{-6}	Good	5183
–	10.4×10^{-6}	Good	5183
67	–	Good	5154
–	–	Good	5556
10	6.3×10^{-6}	Good	Monel
6	$0.5–1.2 \times 10^{-6}$(j)	Good	Invar or Inco "A"
4.0	4.3×10^{-6}	Requires special welding chamber	6 Al, 4 V titanium
–	–	Castings used for low-pressure parts	

5000 series which have high strength and toughness in the as-welded condition. More recently, the coming of the plasma-arc, inert-gas cutting process has speeded the fabrication of these metals.

In the alloys of the 3000 series (1% Mn), 3003 is the only one which is used to any extent. It is the easiest of all aluminum alloys to weld, especially where vacuum tightness is essential. Normally, it is welded with 1100 rod, which results in a tensile strength of 14,000 psi. This low strength is the chief limitation of the alloy.

The alloys in the 5000 series (containing various amounts of magnesium, some also with slight manganese additions) are used to a considerable extent for cryogenic vessels. Their tensile strength increases with alloy content, reaching 42,000 psi. for the 5456 alloy. Although the alloys are weldable, they suffer from hot shortness under certain circumstances and they are more prone to cracking than 3003. Welding problems such as porosity and oxide folds develop with increasing magnesium content. At the same time, impact properties decrease at low temperature, although there is no evidence of a transition temperature or a shift to a notch-brittle condition. The fatigue strength of aluminum alloys is low – in the 7000 to 15,000 psi. range – and this is not improved by increased magnesium content.

Alloys in the 6000 series (containing magnesium silicide) are used primarily for extruded shapes and forgings. They can be welded, but cracking due to hot shortness is a serious problem and the as-welded strength is lower than for some of the alloys in the 5000 series. The latter are preferred where welding is a major factor.

High-Nickel Alloys and Other Metals

Pure nickel or Monel metal is used to a limited extent at cryogenic temperatures, primarily for liquid fluorine (boiling point: −307° F.). Inconel, "K" Monel, and other alloys have specific applications. The properties of these metals are excellent at low temperature; their principal drawback is cost.

Titanium alloys find application where a high strength-to-weight ratio is essential, or where both high and low-temperature properties are required as in certain parts of rockets (see *Metal Progress*, April 1961, p. 72).

Cast iron, although *(Continued on p. 154)*

What Metal Shall I Use . . .

for High-Strength Welded Structures?

Today, as more and more fabricators strive to make their products lighter and stronger, their attention is focusing on high-strength steels and alloys of aluminum and magnesium which can be fabricated into light but strong structures by modern welding techniques. This article presents a compilation of these important materials and discusses how they can be used to best advantage. (K-general; ST, Al, Mg, 7-51)

Steels

IF YOU TAKE A CLOSE LOOK at the steel and fabricating industries, you will find two important trends. First, there is increased emphasis on the importance of lowering construction costs by optimum use of the wide variety of high-strength and constructional alloy steels available and, second, more engineers are recognizing the advantages of welded construction.

Designed for Welding

Whatever the source for these trends, one thing is sure: The steel industry has come up with a wide variety of steels for structural uses which encompasses minimum yield strengths of 32,000 to 110,000 psi. What's more, many of these steels have been designed with weldability in mind.

As a base, we may consider A.S.T.M. A 7-58 T, the basic workhorse of structural specifications. It defines a carbon structural steel having a minimum yield point of 33,000 psi. and a minimum tensile strength of 60,000 to 75,000 psi. But the strength of this steel would vary with section size unless an adjustment were made in composition. Thus, to keep within the minimum strengths specified by A.S.T.M. A 7, steelmakers must add carbon or manganese or both. The result: Weldability of A 7 steel (and its ability to be cold formed) may range from excellent to poor depending on thickness.

Stronger Carbon Steel

To give fabricators a steel of higher strength at only slight increase in cost, a new specification, A 36-60 T, was written. As shown in the

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M-P Fact Sheet on p. 118, it calls for a minimum yield point of 36,000 psi. and tensile strengths ranging from 60,000 to 80,000 psi. Because of the higher yield point, 3000 psi. over that of A 7, significant savings in weight and costs are possible in steel fabrication. And the Fact Sheet indicates another significant feature about A 36 steel – in its maximum permissible thickness of 4 in. in hot-rolled plates, shapes and bars, the steel has a limitation on carbon and manganese content to insure that good weldability is maintained. As with A 7 steel, cold formability of the heavy gages may suffer because of the higher carbon content (0.28%, max.) needed to keep the strength up.

High-Strength, Low-Alloy Steels

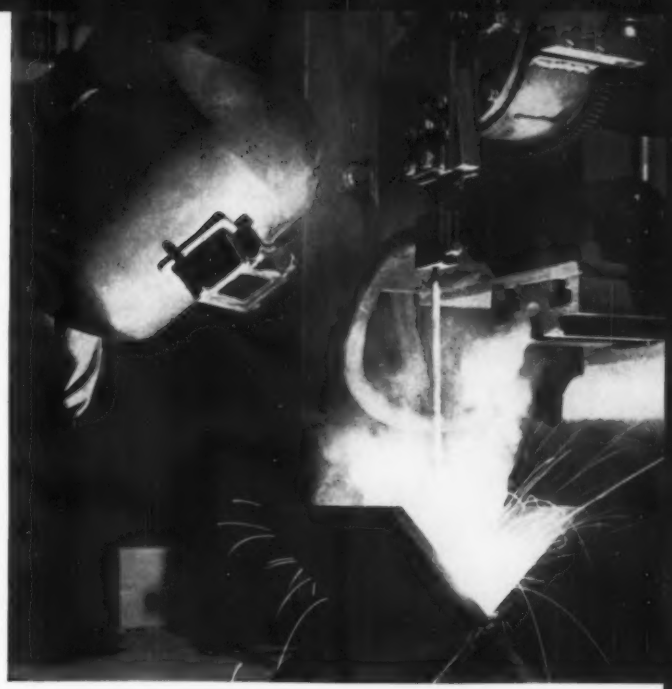
As mentioned earlier, A 36 steel fills the demand for a structural material that gives steel fabricators more flexibility in design and fabrication. This idea is carried through in the other high-strength steels for welded structures. Although they may cost more per ton than carbon structural steel, they permit savings in weight which may actually lead to lower fabrication costs if engineers take advantage of the available strength.

Section Size Affects Strength

For example, A.S.T.M. A 242-55 sets down a broad specification for high-strength, low-alloy steels, which cost more than A 36 steel but are stronger. These steels are available in shapes, bars and plates for welded or riveted construction. Carbon content is restricted to 0.22% and manganese content to 1.25% for good weldability and, as one might suspect, the minimum strength decreases as the thickness is increased. Thus, for gages up to ¾ in., the minimum yield point is 50,000 psi. but for thicknesses of ¾ to 1½ in. and 1½ to 4 in., the minimum yield is reduced to 46,000 and 42,000 psi., respectively.

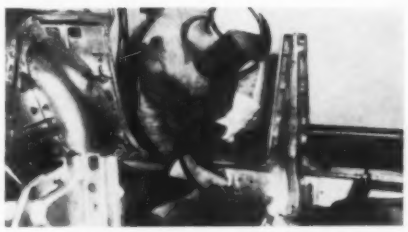
Improved Corrosion Resistance

The M-P Fact Sheet on p. 118 shows that in A.S.T.M. specification A 441-60 T, engineers have a choice of yet another weldable, high-strength, low-alloy steel with the same minimum mechanical properties as those called out in A 242. In fact, some steels meet both specifications as they are presently written. But the basic difference is one of alloy content and, consequently, cost. Steels supplied to meet A 441 are basically manganese-vanadium grades with 0.20% (min.) Cu; they are lower in price



Engineer Studies Weldability

Automatic Welder Joins Magnesium



Welding an Automobile Body

Aluminum Tank for Liquid Hydrogen

High-Strength Steels for Welded Structures

ASTM Designation	Typical Names	Composition, %	Size	Mechanical Properties (Minimum) Yield Point(a), Psi.	Tensile Strength, Psi.	Elongation(b), %
Carbon Structural Steel						
A36-60T		0.28 C (max.)	Shapes	36,000	60,000–80,000	20
		0.28 C (max.)	Bars: ¾ in. and under			
		0.28 C (max.), 0.60–0.90 Mn	Over ¾ in.			
		0.28 C (max.)	Plates: ¾ in. and under			
		0.28 C (max.), 0.80–1.10 Mn	Over ¾ to 1½ in. incl.			
		0.28 C (max.), 0.85–1.20 Mn, 0.15–0.30 Si	Over 1½ to 4 in. incl.			
High-Strength, Low-Alloy Steel						
A441-60T	Tri-Ten, Tri-Steel, Manganese-Vanadium, Yoloy A441, Sheffield Hi-Strength "B", Armco High Strength No. 5	All thicknesses: 0.22 C (max.), 1.25 Mn (max.), 0.30 Si (max.), 0.20 Cu (min.), 0.02 V (min.), 0.04 P (max.), 0.05 S (max.)	¾ in. and under	50,000	70,000	18
			Over ¾ to 1½ in. incl.	46,000	67,000	19
			1½ to 4 in. incl.	42,000	63,000	19
A242-55	Cor-Ten, N-A-X High Tensile, N-A-X Finegrain, Hi-Steel, Tri-Ten, Yoloy E HS, Mayari R, Dynalloy, Republic 50, Tri-Steel, Kaisaloy No. 1, J & L Ni-Cu-Ti High-Strength Forming Steel, Sheffield Hi-Strength "A", Armco High Strength No. 1	All thicknesses: 0.22 C (max.), 1.25 Mn (max.), 0.05 S (max.)	¾ in. and under	50,000	70,000	18
			Over ¾ to 1½ incl.	46,000	67,000	19
			Over 1½ in.	42,000	63,000	19
Columbium-Treated Steels						
	GLX-45-W, EX-Ten 45, AWX-45, Yoloy 45W, INX-45, JLX-45-W, Republic X-45-W, High Strength No. 7, Columbium 45	Not furnished to specific range. Typical analysis: 0.10–0.25 C, 0.4–1.5 Mn, 0.01–0.04 Cb	Up to ⅛ in. incl.	45,000	60,000	18
	GLX-50-W, EX-Ten 50, AWX-50, Yoloy 50W, INX-50, JLX-50-W, Republic X-50-W, High Strength No. 6, Columbium 50			50,000	65,000	16
	GLX-55-W, EX-Ten 55, Yoloy 55W, INX-55, JLX-55-W, Republic X-55-W, Columbium 55			55,000	70,000	14
	GLX-60-W, EX-Ten 60, Yoloy 60W, INX-60, JLX-60-W, Republic X-60-W, Columbium 60			60,000	75,000	12
Heat Treated, Constructional Alloy Steel						
	T-1	0.10–0.20 C, 0.60–1.00 Mn, 0.15–0.35 Si, 0.70–1.00 Ni, 0.40–0.65 Cr, 0.40–0.60 Mo, 0.03–0.08 V, 0.15–0.50 Cu, 0.002–0.006 B, 0.40 P (max.), 0.050 S (max.)	3/16 to 2½ in. incl.	100,000	115,000–135,000(c)	18
			Over 2½ to 6 in. incl.	90,000	105,000–135,000(c)	17(d)
	T-1 Type A	0.12–0.21 C, 0.60–1.00 Mn, 0.15–0.35 Si, 0.40–0.65 Cr, 0.15–0.25 Mo, 0.03–0.08 V, 0.0005–0.005 B, 0.040 P, 0.05 S, 0.01–0.3 Ti	3/16 to 1 in. incl.	100,000	115,000–135,000(c)	18(e)
	N-A-XTRA 80	Not furnished to specific range. Typical analysis includes: 0.14–0.20 C, 0.80 Mn, 0.60 Si, 0.65 Ni, 0.20 Cr, 0.02 P, 0.03 S, 0.06 Zr	⅛ to 1 in.	80,000	100,000(c)	18
	N-A-XTRA 90			90,000	110,000(c)	
	N-A-XTRA 100			100,000	119,000(c)	18
	N-A-XTRA 110			110,000	130,000(c)	18
	Jalloy-S-90	0.10–0.20 C, 1.10–1.50 Mn, 0.15–0.30 Si, 0.20–0.30 Mo, 0.05 P, 0.04 S	to 1 in. incl.	90,000	105,000(c)	18
	Jalloy-S-100			100,000	115,000(c)	18
	Jalloy-S-110			110,000	125,000(c)	18
	SSS-100	0.12–0.20 C, 0.40–0.70 Mn, 0.20–0.35 Si, 1.40–2.00 Cr, 0.40–0.60 Mo, 0.20–0.40 Cu, 0.04–0.10 Ti, 0.0015–0.005 B, 0.040 P (max.), 0.040 S (max.)	3/16 to 1 in. incl.	100,000	115,000(c)	18
	SSS-100A	0.13–0.21 C, 0.40–0.70 Mn, 0.20–0.35 Si, 0.85–1.20 Cr, 0.15–0.25 Mo, 0.20 Cu (min.), 0.040 P (max.), 0.040 S (max.), 0.04–0.12 Ti, 0.0015 B (min.)	3/16 to 1 in. incl.	100,000	115,000–135,000	18(e)

(a) Yield strengths of heat treated, constructional alloy steels are listed rather than yield points.

(b) Elongation in 8 in. for carbon structural, high-strength low-alloy and columbium-treated steels; elongation in 2 in. for heat treated, constructional alloy steels.

(c) Typical.

(d) Minimum elongation is 16% in sections over 4 to 6 in. (inclusive) thick.

(e) Minimum elongation is 16% in sections ¾ to 1 in. (inclusive) thick.

	Outstanding Characteristics	Welding Characteristics	Applications
	Engineering properties same as those of ASTM A7 steel except for minimum yield strength which is 9% higher. Atmospheric corrosion resistance is improved if copper (0.20% or more) is added.	Limitation on carbon and manganese contents insures good weldability. E60XX electrodes are satisfactory.	Same as ASTM A7 and A373 steels. Higher yield point permits weight and cost savings.
	Atmospheric corrosion resistance two times that of carbon steel. Costs less than grades with greater corrosion resistance. Hot forming recommended for thickness over ½ in.	Good weldability. Use E60XX or E70XX electrodes.	Bridges, buildings, construction machinery, ordnance handling equipment, railroad car underframes, pipeline fittings.
	Many of the steels meeting ASTM A242 (but not all) exhibit atmospheric corrosion resistance four to six times that of carbon steel. Endurance limit 50% higher than ASTM A7 steel; cold-forming properties are at least equivalent and often superior to A7 steel.	Weldability superior to that of carbon steel. E60XX electrodes satisfactory; E70XX preferred for multipass welds.	Bridges, buildings, construction machinery, ordnance handling equipment, railroad car underframes, pipeline fittings.
	Combine strength and weldability at relatively low cost. Basically, these are carbon steels with columbium added to improve strength. Low carbon and manganese insure good weldability. Resistance to corrosion can be increased by adding copper.	Weldability equivalent to that of mild carbon steels. E60XX or E70XX electrodes are recommended.	Auto and truck parts, pipelines, other applications where strength, good weldability and formability are required.
	Yield strength about three times that of structural carbon steel, high toughness, and atmospheric corrosion resistance (four to six times that of carbon steel). Steels with leaner alloy content, such as T–1 Type A, have the same mechanical properties as T–1 steel but atmospheric corrosion resistance is less (two times that of carbon steel) and availability is limited to thicknesses of up to 1 in.	For manual arc welding, low-hydrogen electrodes of the E7015, –16, –18 to E12015, –16, –18 classifications, preferably those which match the strength of the base metal. Preheat usually neither recommended nor required. Heat input must be carefully controlled; stringer-bead welding is recommended. Can also be welded by submerged-arc and inert-gas-shielded metal-arc processes.	Applications similar to those of high-strength low-alloy steels. Higher strength of heat treated grades permits less steel to be used, often at a cost savings despite their greater cost per ton. These steels have been used in such applications as cranes, booms, earth-moving equipment, trailer and truck frames and bridges, pressure vessels.

than A 242 steels. This specification is now commonly used for weldable steels when improved resistance to atmospheric corrosion is not required. Many of the steels meeting A 242 contain nickel, copper and chromium and will thus exhibit atmospheric corrosion resistance about four to six times that of A 7 steel; A 441 is better than A 7 in this respect (as long as the same amount of copper is not added to the A 7 steel) but only by a factor of about 2. The Fact Sheet also notes a precaution. As A 242 is written, it does not specifically define the required degree of corrosion resistance; designers, if they want the enhanced corrosion properties usually associated with A 242, should specify "atmospheric corrosion resistance at least four times that of carbon structural steel".

New Specification

The confusion between A 242 and A 441 is now being considered by A.S.T.M. and it is probable that a more definitive specification will evolve. In addition S.A.E. has been working on a specification (actually a revision of S.A.E. 950) for carbon-manganese, high-strength steels and high-strength, low-alloy steels, S.A.E. 945 and 950. These grades would be supplied with minimum yield strengths of 45,000 and 50,000 psi., respectively, depending on thickness. The specification sets forth maximum chemical contents for a total of six grades of these steels. The addition of copper, silicon or other elements for increased corrosion resistance is left to negotiation.

Also included in the tentative specification is a table which lists the relative weldability, formability and toughness of the six proposed grades based on their respective chemical limits.

As it stands now, the proposed standard would prove quite valuable in defining areas which have been treated vaguely in the past. It should be pointed out, however, that the specification has not been approved in its present form. Further consideration of its wording by the appropriate S.A.E. committee seems likely.

Another steel, covered by A.S.T.M. A 440-59 T and supplied to the same minimum yield points as A 242 and A 441, is sometimes used in welded structures. It is primarily intended for bolted and riveted construction because of the high carbon and manganese limits (0.28% and 1.10 to 1.60%, respectively) allowed by the specification, and for this reason it is not listed on the Fact Sheet. But A 440 steel is cheaper than either A 242 or A 441, and some fabricators (of low-pressure gas tanks, for example) have learned to join it with reliable welds. Without special precautions, however, A 440 is not recommended for welding.

Welding High-Strength, Low-Alloy Steels

Any of the high-strength, low-alloy steels shown on the Fact Sheet can be welded by the usual techniques – metal arc, submerged arc, resistance and gas welding and inert-gas-shielded tungsten or metal-arc welding – without affecting corrosion resistance. Special alloy electrodes are not essential, but the choice of electrodes depends on the joint efficiency that is required. Where 100% efficiency is not necessary, covered electrodes in the A.S.T.M. A 233-58 T or E 60XX are satisfactory. Higher joint efficiencies can be obtained by using low-alloy E 70XX or A.S.T.M. A 316-58 T electrodes. These are also recommended for multiple-pass welding and when heavy sections are joined. Low-hydrogen electrodes are preferred.

Spot welding techniques for high-strength, low-alloy steels are essentially the same as those for structural carbon steels. Higher resistivity and greater sensitivity to time and current may require that welding current be slightly lower and the pressure slightly higher.

For gas welding, high-strength rods GA 65 or A.S.T.M. A 251-46 T may be used.

Where Columbium-Treated Steels Fit In

The need for inexpensive high-strength steels led to the development of the columbium-bearing grades with minimum yield points of 45,000, 50,000, 55,000 and 60,000 psi. Columbium is the strengthening element in these grades (it refines the grain size), and by adding only 0.01 to 0.04% of it to semikilled carbon steels, yield point is increased by 10,000 to 13,000 psi.

Columbium-treated steels find most application where strength, formability and low cost are desired. Their corrosion characteristics are the same as those of carbon steels, but small amounts of copper can be added for improvement. Although specified only on the basis of the minimum yield point, the columbium steels usually contain less than 0.25% C.

For this reason they can be welded by all conventional gas and electric processes. No pre or postweld heating is required; electrodes in the E 60XX or E 70XX are recommended.

High strength, low cost and excellent weldability have made columbium-treated steels some of the most useful of the high-strength grades. Basically, they have potential in almost any application where carbon steels are used because of the cost advantage that is made possible by use of lighter sections. Maximum thickness is limited to about ⅜ in.; processing techniques and the question of toughness of sections thicker than ⅜ in. are now under investigation.

Applications for columbium-treated steels have been in trucks and auto parts such as channels, wheels, tank trucks and even concrete mixers. Recent interest has also come from the pipeline industry. In one instance some 800 repair sleeves for a pipeline were fabricated (by hot pressing, then welding in the field) from a grade having a 55,000-psi. minimum yield strength. Wall thickness of the sleeves was 0.344 in. compared with 0.500 in. needed for carbon steel to provide the same allowable working pressure. The thinner wall permitted better fit up in the field, and estimated cost savings amounted to at least 35%.

Heat Treated Steels Provide High Strength

Up to this point, the steels which have been discussed are those which need no heat treatment to develop strength. These grades — carbon structural, high-strength, low-alloy and columbium-treated — are supplied in the as-rolled, as-annealed or normalized condition. To obtain yield strengths much above 60,000 psi., more alloying elements must be added and the steel must be quenched and tempered. The result is the heat treated, constructional alloy steels which extend the available strength levels in weldable steel to 110,000 psi. minimum yield.

Carefully Controlled Analysis

As noted in the Fact Sheet, the various proprietary grades contain not more than 0.21% C. There are sufficient amounts of alloying elements such as nickel, chromium and molybdenum for through hardening in the thicknesses that are available (quenching produces a structure of martensite and lower bainite) and small quantities of carbide formers such as vanadium which retard softening during tempering and permit tempering at high temperatures for maximum ductility and toughness.

The significant feature of these steels is that, in addition to their high strength level, they are designed for welding. They permit reductions in weight and cost of welded structures and are being used in bridges, earth-moving and construction equipment, pressure vessels, and in transportation and materials-handling equipment. *(Continued on p. 158)*

Aluminum

CHOOSING THE BEST ALUMINUM ALLOY and temper for a particular welded structure may seem complicated because of the many different combinations that are available. But quite a few of the alloys and tempers are intended for special service requirements such as finish, compatibility with a certain chemical, and temperature, and the actual problem of selection does not prove particularly difficult. Of course, final selection of materials, welding process and joint design requires detailed information. We can, however, classify aluminum alloys for high-strength welded structures in three rather distinct groups based primarily on strength and economics.

Aluminum-Magnesium Alloys

Consider, for example, the aluminum-magnesium series of alloys shown in the M-P Fact Sheet, p. 122. All bear the 5xxx designation and are designed as a group to take the fullest advantage of the inert-gas-shielded arc-welding processes (either tungsten or metal arc). These processes provide the highest joint strength, good ductility and ease of welding. The parent metal also has a good range of strength and workability. Because alloys in the 5xxx series do not respond to heat treatment, the strongest tempers are available only in cold-worked products such as sheet and plate. Thus, the aluminum-magnesium alloys find their principal applications in structures that are fabricated predominantly from sheet and plate and where welding is the method of joining. It should be pointed out, however, that welding tends to anneal the metal. Thus, in most instances, the strengthening effect of cold working is not counted in welded structures.

This article was prepared with the assistance of: Aluminum Co. of America, Pittsburgh; Kaiser Aluminum & Chemical Corp., Oakland, Calif.; Reynolds Metals Co., Richmond, Va.

The M-P Fact Sheet lists 31 alloy and temper combinations in the 5xxx series of alloys, their typical properties, standard products, and compositions. Obviously, the best choice for a given application is not always clear cut. In any one alloy, the stronger tempers require a larger bend radius, but the strength of the weld is approximately independent of temper. We must, therefore, decide whether weld strength or parent-metal strength should control design.

Balancing Cost and Strength

In this group there is a small price increase for the stronger alloys, but the various tempers offered do not involve appreciable price differentials. Thus, it can be determined from the M-P Fact Sheet that a 37,000 psi. yield strength can be had in both 5456-H 321 and 5086-H 34. Because the former alloy is a bit more expensive, it must be decided whether the advantage in weld strength (45,000 psi. compared with 37,000 psi. as shown in M-P Fact Sheet) is of sufficient importance to offset the slightly higher price and lower ductility.

Heat Treatment Gives High Strength

In the second group are two alloys which are nearly identical. The older one, 6061, has been used for many years as the standard general-purpose structural alloy. It is made in every commercial form and is widely used. The other alloy in the group, 6062, is a slight modification that was developed to improve extrusion characteristics, and other aspects that are of interest to a user are the same for the two alloys.

The strength of 6061 and 6062 is developed by solution heat treating, quenching in water (T 4 temper) and then artificially aging to the T 6 level. Thus, the temper is independent of any cold working that may have been used in fabrication, and the hot-worked products (for example, extrusions and rolled structural shapes) have about the same level of strength as sheet after heat treatment.

This is the distinct advantage which these alloys have over those in the aluminum-magnesium group and is the determining factor in structural applications where the design is controlled by buckling or by parent-metal strength rather than by the strength of the welds. There is another general field where the advantage of achieving maximum strength by heat treating rather than by cold rolling is important. Parts which require the annealed temper to permit forming, but still need a good measure of strength in service are best made of a heat treatable alloy. If, in addition, they are to be fabricated by welding, either 6061 or 6062 is a logical choice.

These two alloys offer more strength in the parent metal for the money than the 5xxx group by a small margin in sheet and a larger one in shapes, and this frequently outweighs the fact that the welds are not as strong.

High Strength-to-Weight Ratios

The third group is comprised of three alloys which have the common characteristic that higher strength-to-weight ratios can be achieved, but extra cost and extra effort is

Alloy	Nominal Composition, %	Temper	Yield Strength, Psi.
5456	5.25 Mg, 0.80 Mn, 0.10 Cr	O	23,000
		H321	37,000
		H112	24,000
		H311	33,000
		H323	38,000
		H343	43,000
		H24	41,000
5083	4.45 Mg, 0.80 Mn, 0.10 Cr	O	21,000
		H112	28,000
		H321, H113	33,000
		H323, H32	36,000
		H343, H34	41,000
5086	4.0 Mg, 0.45 Mn, 0.10 Cr	O	17,000
		H32	30,000
		H34	37,000
		H36	41,000
		H112	19,000
5154	3.5 Mg, 0.25 Cr	O	17,000
		H32	30,000
		H34	33,000
		H36	36,000
		H38	39,000
		H112	17,000
5454	2.75 Mg, 0.80 Mn, 0.10 Cr	O	17,000
		H32	30,000
		H34	35,000
		H112	18,000
		H311	26,000
6061	1.0 Mg, 0.60 Si, 0.25 Cu, 0.25 Cr	O	8,000
		T4, T451	21,000
		T6, T651	40,000
6062	1.0 Mg, 0.60 Si, 0.25 Cu, 0.06 Cr	O	8,000
		T4, T451	21,000
		T6, T651	40,000
2219	6.3 Cu, 0.30 Mn, 0.10 V, 0.15 Zr	O	10,000
		T42	27,000
		T31	37,000
		T37	49,000
		T62	42,000
		T81	53,000
		T87	58,000
2014	4.4 Cu, 0.80 Si, 0.80 Mn, 0.40 Mg	O	14,000
		T4, T451	42,000
		T6, T651	60,000
7178	2.0 Cu, 2.7 Mg, 6.8 Zn, 0.30 Cr	O	15,000
		T6, T651	78,000

Aluminum Alloys for Welded Structures and Components

Typical Mechanical Properties*						
Tensile Strength, Psi.	Elongation (in 2 In.), %	Brinell Hardness (500 Kg. on 10 Mm. Ball)	Shear Ultimate, Psi.	Standard Products	Characteristics Governing Selection	Applications
45,000	24	75	28,000	Sheet, plate, extruded tube, pipe and shapes	Excellent weldability. Strength increases as magnesium content goes up. Does not require heat treatment	Structures designed on basis of strength and ductility of welds including dump trucks, rock bodies, bulk haulers, truck tanks, boats, cryogenic tanks and equipment, chemical processing equipment, elevators for aircraft carriers
51,000	16	90	30,000	Sheet, plate		
45,000	22	75	28,000	Extruded tube, pipe and shapes		
47,000	18	86	28,000	Extruded tube, pipe and shapes		
51,000	10	90	30,000	Sheet		
56,000	9	94	33,000	Sheet		
54,000	12	92	30,000	Sheet		
42,000	22	73	26,000	Plate, forgings, extruded tube, pipe and shapes		
44,000	16	80	26,000	Extruded tube, pipe and shapes		
46,000	16	84	27,000	Sheet, plate		
47,000	10	86	28,000	Sheet		
52,000	9	92	30,000	Sheet		
38,000	22	65	23,000	Sheet, plate, extruded tube, pipe and shapes		
42,000	12	77	25,000	Sheet, plate		
47,000	10	86	27,000	Sheet, plate		
50,000	8	92	30,000	Sheet		
39,000	14	68	25,000	Sheet, plate, extruded tube, pipe and shapes		
35,000	27	58	22,000	Extruded tube and shapes		
39,000	15	67	23,000	—		
42,000	13	73	25,000	—		
45,000	12	78	27,000	—		
48,000	10	80	28,000	—		
35,000	25	63	22,000	Extruded tube and shapes		
36,000	22	62	23,000	Sheet, plate, extruded shapes		
40,000	10	73	24,000	Sheet, plate		
44,000	10	81	26,000	Sheet, plate		
36,000	18	62	23,000	Plate, extruded shapes		
38,000	14	70	23,000	Extruded shapes		
18,000	25	30	12,000	Sheet, plate, drawn tube and pipe, extruded tube, pipe and shapes, rolled shapes, rod, bar, forgings, impacts	Standard structural alloys in all forms	Structures designed on basis of base-metal properties. Highway sign structures, scaffolds, materials handling equipment, piping systems, large radar antennas
35,000	22	65	24,000			
45,000	12	95	30,000			
18,000	30†	30	12,000	Drawn tube and pipe, extruded tube and shapes		
35,000	25†	65	24,000			
45,000	17†	95	30,000			
25,000	20	—	—	—	Most weldable of the heat treatable aluminum alloys. Produces strong, reliable joints	Applications requiring maximum strength-to-weight ratio. Military pressure vessels, secondary aircraft structures; experimental structures
53,000	20	—	—	—		
54,000	17	100	33,000	—		
60,000	11	117	37,000	—		
61,000	11	115	37,000	—		
70,000	11	130	41,000	—		
70,000	10	130	41,000	—		
27,000	18†	45	18,000	Plate, extruded tube, pipe and shapes, rod, bar forgings, impacts	Strong parent metal	
62,000	20†	105	38,000			
70,000	13†	135	42,000			
33,000	15	60	22,000	Sheet, plate, extruded tube and shapes	Strongest parent metal. Welded structures of this alloy are still in experimental stage	
88,000	10	160	52,000			

*Properties will vary according to such factors as product thickness. For design purposes, guaranteed minimum properties, available from the Aluminum Association, N. Y., or the manufacturer, must be used.

†1/2-in. round specimens; all others: 1/16-in. flat specimens.

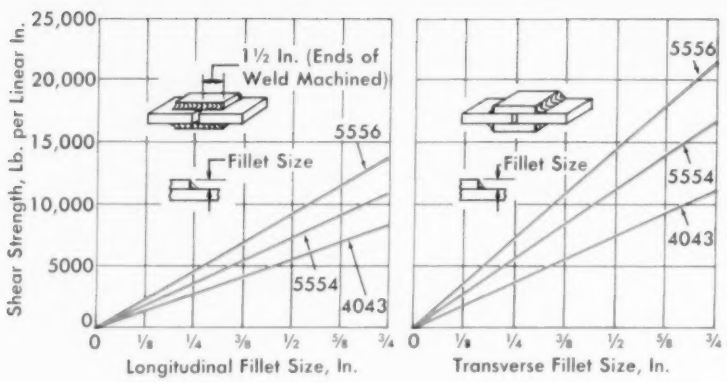


Fig. 1 – Effect of Longitudinal and Transverse Fillet Size on the Average Shear Strength of Three Filler Alloys Deposited by Inert-Gas, Tungsten-Arc or Consumable-Electrode Methods. Inset on each curve shows type of specimens that were used

required all along the line. The most weldable alloy in this group is 2219 (see *Metal Progress*, September 1961, p. 87) and it is so new that there are relatively few actual applications. The strength of this alloy after artificial aging is dependent on the amount of cold work performed after quenching. The T 62 temper, which requires no cold work, is the strongest that is generally applicable to welded structures heat treated and aged after welding. Usually the T 81 or T 87 temper is achieved by welding the alloy in the T 31 or T 37 condition and then aging the complete assembly. This approach offers the highest parent-metal strength that is obtained in an aluminum alloy that can be termed "weldable" in the usual sense. Since the weld strengths are not as high as those of the parent-metal, care must be exercised in design. Expedients such as placing welds away from extreme fibers of beams, and the use of increased thickness at the welds are required to obtain a strong struc-

MP Fact Sheet

Strength of Aluminum Arc-Welded Butt Joints

Alloy and Temper	Thickness Range, In.	Postweld Treatment	Filler Alloy*	Tensile Strength, Psi.		Average Free Bend Elongation, %	Guided Bend Radius
				Average	Minimum		
5456	Up to 2	None	5556	45,000	42,000	28	3½t
5083	Up to 2	None	5556	44,000	40,000	37	2t
5086	Up to 2	None	5556	37,000	35,000	38	2t
5154	Up to 2	None	5556	34,000	30,000	40	2t
5454	Up to 2	None	5554	35,000	31,000	40	2t
6061–T6†	Under 1	None	5556	27,000	24,000	17	8½t
6061	Under 1	Solution treat and age	4043	43,000	–	10	–
6061–T4	Under 1	Age	5556	40,000 (tentative)	–	–	–
2219–T81; T87	Up to 1¼	None	2319	40,000	–	20	–
2219–T31; T37	Up to 1¼	Age	2319	40,000	–	20	–
2219	Up to ½	Solution treat and age	2319	54,000	–	13	–
2014–T6	Up to ½	None	2319	45,000	–	–	–
2014	Up to ½	Solution treat and age	2319	55,000	–	–	–
7178–T6	Up to ½	None	5556	55,000 (experimental)	–	–	–
7178	Up to ½	Solution treat and age	5556	75,000 (experimental)	–	–	–

*A list of recommended filler alloys can be found in the Welding Handbook, Fourth Edition, 1960, American Welding Society, p.69A.29.
†Alloy 6062 will perform essentially the same as 6061.

ture which will have minimum weight.

Alloy 2014 has been used quite extensively in a number of missiles (Thor, Titan and Hound Dog) and a few other projects where it was possible to overcome by design the shortcomings of the welds. Most of these have involved welding in the T 6 temper, using 4043 filler. The recommendation to use 2319 filler is a recent one designed to provide more strength and ductility in the joint at small expense in weldability.

Welding Aluminum-Zinc Alloys

Some attempts have been made to use the aluminum-zinc alloys in weldments because of their strength. Alcoa has found that the strongest commercial alloy in this group, 7178, is easier to weld than the better-known 7075. Experimental pressure vessels of 7178 have repeatedly developed the full tensile properties of the parent metal and have also exhibited adequate ductility under pressure. Only circumferential butt welds were used. The metal thickness at the welds was double that of the rest of the sidewall. A removable back-up was used, and the welds were dressed on both sides. However, cracking tendencies are such that it does not seem prudent to attempt complicated weldments in alloy 7178.

Choosing a Filler Alloy

Finally, a word of explanation about choice of filler alloys. The best fillet weld is made with a filler alloy that is 40 to 50% stronger than the heat-affected parent metal to which it is fused. This accounts for the recommendation of 5556 as a general-purpose, high-strength filler alloy even on parent metal of lower magnesium content. With 6061 welded with 4043 filler and heat treated after being welded, there is some mixing of magnesium from the parent metal into the weld head. The result: An alloy is formed that responds to heat treatment. This action becomes less effective in thick material. The choice of filler alloys for the stronger alloys is restricted even more closely by the desire for high strength on the one hand and the problem of weld cracking on the other.

Many welded structures today are intentionally designed to be fabricated primarily by means of fillet welds. This is largely because fillet welds are so much easier to fit up than are butt welds. Figure 1 shows how fillet size affects the shear strength of welds made with three filler alloys, 5556, 5554 and 4043. The curves indicate that it may be beneficial to use filler alloys which are stronger than the base metal since less weld metal will be needed to obtain a joint of adequate strength.

In summary, we find that aluminum parent metals and filler alloys are highly developed and standardized for high-strength structures where economy and lightness must strike a normal balance. In more exotic structures, where weight must be shaved even at high cost, aluminum is still in a development stage, but progress is being made.

Magnesium

*By LLOYD LOCKWOOD**

MAGNESIUM ALLOYS LISTED in the M-P Fact Sheet on p. 126 can be welded by most of the major processes, but the gas-shielded arc and spot-welding techniques are the most common. Weld-strength efficiencies range from 75 to 100%, with most magnesium alloys exhibiting better than 85% efficiency.

Gas welding, using oxy-fuel gas mixtures, was the first and only welding process for magnesium for a number of years. Because of the corrosive nature of the flux needed to protect the molten weld puddle and the difficulty of completely removing residual flux from the joint, it is now employed only in the smaller shops and on low-production items. Probably the major area for gas welding of magnesium is in emergency repairs.

Welding Characteristics

There are certain basic characteristics of magnesium which must be considered in welding. Without exception an increase in alloy content also increases the solidification range but lowers the shrinkage and the solidus and liquidus temperatures. In those alloys containing aluminum and zinc (AZ31B, AZ61A and AZ80A), the aluminum content aids weldability, but zinc induces hot shortness and may cause weld cracking. This trouble is not usually encountered unless the zinc content exceeds 1%.

*Research and Development Engineer, Metallurgical Laboratory, Dow Metal Products Co., Div. of Dow Chemical Co., Midland, Mich.

Magnesium Alloys for Welded Structures and Components

Alloy	Composition, %	Temper	Mechanical Properties*								
			Base Metal			Weld Metal†					
						Weld Bead Intact			Weld Bead Flush		
			Yield Strength, Psi.	Tensile Strength, Psi.	Elongation (in 2 In.), %	Yield Strength, Psi.	Tensile Strength, Psi.	Elongation (in 2 In.), %	Yield Strength, Psi.	Tensile Strength, Psi.	Elongation (in 2 In.), %
Sheet and Plate											
AZ31B	3.0 Al, 0.4 Mn, 1.0 Zn	O	22,000	37,000	21	19,000	35,000	9	17,000	35,000	10
		H24	32,000	42,000	15	23,000	37,000	4	19,000	36,000	5
		F	29,000‡	38,000‡	15‡	–	–	–	–	35,000‡	12‡
ZE10A	1.2 Zn, 0.2 rare earths	O	20,000	33,000	23	18,000	31,000	7	15,000	30,000	8
		H24	28,000	38,000	12	20,000	33,000	3	17,000	31,000	5
HK31A	3.3 Th, 0.7 Zr	H24	30,000	38,000	9	22,000	31,000	2	31,000	20,000	4
HM21A	0.6 Mn, 2.0 Th	T8	34,000	25,000	10	30,000	22,000	2	19,000	30,000	4
Extrusions											
ZK21A	2.3 Zn, 0.6 Zr	F	28,000	38,000	4	–	–	–	–	33,000	5
AZ80A	8.5 Al, 0.18 Mn, 0.5 Zn	F	36,000	49,000	11	–	–	–	–	42,000	11
HM31A	1.2 Mn (min.), 3.0 Th	T5	33,000	42,000	10	20,000	30,000	2	–	–	–
AZ61A	6.5 Al, 0.2 Mn, 1.0 Zn	F	33,000	45,000	16	–	–	–	–	40,000	8
ZK60A	5.5 Zn, 0.5 Zr	T5	41,000	52,000	9	–	–	–	–	–	–

*Properties listed are those of sheet, extrusions and arc-welded joints.

†For AZ31B, ZE10A, ZK21A, AZ80A, AZ61A use filler rod alloy AZ61A or AZ92A. For HK31A, HM21A, HM31A use filler rod alloy EZ33A. ZK60A should not be arc-welded.

‡Properties of extrusions (base metal and arc-welded joints).

Those magnesium alloys without aluminum but with a relatively large amount of zinc, such as ZK60A, lend themselves very well to resistance welding, but arc welding is not recommended because of the cracking tendency.

Magnesium alloys containing thorium, which provides good strength at elevated temperatures, exhibit excellent weldability. Furthermore, these alloys do not require stress relief after welding as do AZ31B, AZ61A and AZ80A, which must be stress relieved after arc welding to prevent stress-corrosion cracking.

As mentioned earlier, magnesium alloys can be arc welded either by the gas-shielded tungsten-arc or gas-shielded metal-arc methods. Direct current machines with continuous am-

Outstanding Characteristics and Typical Uses
Best combination of strength, weldability and formability. Requires postweld stress relief at 500° F., 15 min. (AZ31B–O) or 300° F., 60 min. (AZ31B–H24). Uses include aircraft skin and control surfaces and missile body extrusions, materials handling equipment, luggage. Also available in extruded form.
Excellent toughness, postweld stress relief not required but treatment at 500° F. for 30 min. (ZE10A–O) or at 300° F., 60 min. (ZE10A–H24) will reduce assembly stresses. Applications: storage bins, shipping containers, similar industrial uses.
Retains strength at elevated temperatures; excellent weldability. Postweld stress relief not necessary but treatment at 500° F. for 30 min. will reduce assembly stresses. Used for aircraft skin and control surfaces and electronic control housings for missiles, skin for body and fins. Suitable for temperatures up to 400 to 600° F.
High strength at elevated temperatures. Excellent weldability. Postweld stress relief not required but treatment at 700° F. for 30 min. will reduce assembly stresses. Used for aircraft skin and control surfaces, missile body and fin skins and forged ring stiffeners which reach 600 to 750° F.
Good strength and weldability. Postweld stress relief not required. Companion extrusion alloy for ZE10A sheet and plate.
High strength and good weldability. Requires postweld stress relief at 500° F., 15 min. Used as forgings and solid extruded shapes where high strength and weldability are required. Aircraft engine and landing gear forgings; extruded stiffeners and structural members.
High strength at elevated temperature. Excellent weldability. Postweld stress relief not required, but heating to 500° F. for 30 min. will reduce assembly stresses. Extruded aircraft and missile parts for use at elevated temperatures.
Higher strength than AZ31B at slight sacrifice in formability and weldabilty. Stress-corrosion cracking prevented by postweld treatment at 500° F. for 15 min. (AZ80A–F) or 400° F. for 60 min. (AZ80A–T5). Same uses as AZ31B but where higher strength is required. Examples: yard ramps and airframe members.
High-strength extrusions with good toughness. Good alloy for resistance welding but arc welding is not recommended. Uses: forged and extruded aircraft and missile parts requiring high strength including extruded floor beams and forged engine parts and control brackets.

perage control and a-c. machines with a high-frequency arc stabilizer are recommended for gas-shielded tungsten-arc welding of magnesium. Both a-c. and d-c. machines are used on thin gage material, but on magnesium over 3/16 in. thick, a-c. machines are preferred because of their better penetrating power or arc cleaning action.

For gas-shielded metal-arc welding a d-c. power source of the constant potential rather than the constant current type should be used.

Stress Relieving

Stress relieving after arc welding is necessary to prevent stress-corrosion cracking of AZ31B, AZ61A and AZ80A alloys. The thorium-containing alloys developed for applications at elevated temperatures, the tough, sheet alloy, ZE10A, which contains rare earths and zinc, and the zinc-zirconium extrusion alloy, ZK21A, do not require stress relief after welding. These alloys, however, may sometimes be given a stress-relief treatment to provide a stress-free assembly or to size or straighten the weldment. The postweld stress-relief treatments given in the Fact Sheet should be used.

Resistance Spot Welding

Spot welding is the most widely used type of resistance welding on magnesium alloys. Assemblies fabricated in this manner are mostly for low-stress applications such as cabinetry.

The essential requirements for spot welding magnesium alloys include high welding current, positive control of welding pressure, an accurate control of welding time and rapid follow-up of the electrodes. Equipment in which these factors are controlled electronically or are part of their design (a low inertia welding head, for example) are recommended. Alternating-current, three-phase machines are preferred although single phase is satisfactory. Direct-current, stored-energy machines are also widely used. The electrostatic type of stored-energy machine, with a time-to-peak current of 10 to 20 millisec., and a high transformer turns ratio (480 to 1) are preferred. Electromagnetic, d-c., stored-energy machines have received limited use to date on magnesium alloys.

For successful magnesium spot welding and to insure maximum joint strength, the following procedure must be observed:

- Surfaces to be welded must be perfectly clean. (There must be less than 50 microhms surface resistance.)
- Electrode tips must be of high conductivity with water cooling to within ⅜ in. of the end.
- Condensation on the electrode tips must be avoided.
- Tips must be cleaned often to avoid copper pickup.

What Precoated Metal Shall I Use?

Preplated, prepainted and vinyl-laminated metals offer product designers an unlimited choice of colors, textures, patterns and finishes. These composite materials are generally available as flat or coiled sheet and strip, but in special instances plate, wire and tubing can be furnished. (L-general, 8, 17-57)

THE ADVANTAGES of starting fabricating operations with precoated metal stock are many, not the least of which is the potential for reducing production costs without compromising appearance or quality. Manufacturers may select either a metallic coating, applied by electroplating or hot dipping, or an organic finish, which may be an embossed plastic, a vinyl laminate, or a prepainted coating.

Preplated Metals

As indicated in the M-P Fact Sheet, chromium, nickel, brass, or copper can be electroplated on steel or alloys of aluminum, zinc, and copper to provide a wide range of properties and fabricating characteristics.

When handled with reasonable care, preplated metals – finished on one or both sides – can be fabricated in much the same manner as ordinary metals. These materials, available in bright or satin finishes in many textures and patterns, come in popular gages and widths (up to 0.108 in. thick and 24, 30, 36, 48, and up to 60 in. wide, depending on supplier and product type) and tempers (dead soft to full hard).

Preplated metals may be deep drawn, bent, and roll-formed using procedures suitable for the base metal. Hydraulic presses are preferred over mechanical presses because deeper draws are possible and less distortion is obtained. Joining is accomplished by mechanical fasteners or by spot or stud welding. Polished alloy tips, water cooled, are recommended for spot welding operations. Suitable soldering techniques are also available for most preplated metals.

Steels that are electrocoated with zinc and tin are easier to spot weld than the heavier coated, hot-dipped metal. The product is characterized by excellent adhesion of the coating and a uniform, smooth surface. When properly treated (phosphated), zinc-coated sheet is particularly valuable to manufacturers who do not have paint-base pretreatment facilities.

Hot Dipped Coatings

Although zinc-coated steel has excellent corrosion resistance and can be readily formed, special conditions are required for successful welding. Close control of welding schedules (time, pressure, heat) as well as use of a direct welding circuit (one weld per cycle) aid in producing welds on standard galvanized sheet. Differentially coated sheets are also available for spot welding applications. Maximum corrosion resistance is provided on one side with a normal zinc coating; welding is aided by a much thinner coating on the other side.

Demands by the auto, major appliance, and

other industries for galvanized steel with an improved surface finish after painting have resulted in the introduction of spangle-free sheet. The base metal carries a standard 1.25-oz. zinc coating for full corrosion protection. For surface requirements falling between standard and spangle-free sheets, a minimum spangle sheet is also available. All of these products can be temper rolled to further improve the surface. Important to design engineers, these wider galvanized sheets (in gages 8 through 30 and widths up to 72 in.) possess a coating which will withstand as much forming as the base metal without peeling or cracking.

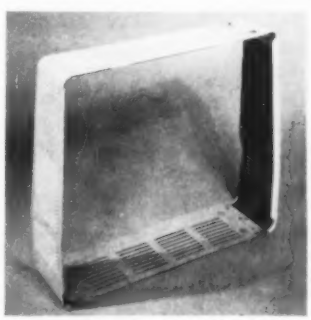
Galvanized Steel Is Now Available in 72 in. Widths

Aluminum-Coated Steel

Available in two grades, aluminum-coated steel offers excellent corrosion resistance and heat reflectivity. The first type, coated with an aluminum-silicon alloy, can be exposed to temperatures up to 900° F. without discoloration and up to 1250° F. without destructive scaling. The material withstands moderate forming, drawing, and spinning operations, and it can be bent 180° over a diameter of 2t without flaking or peeling.

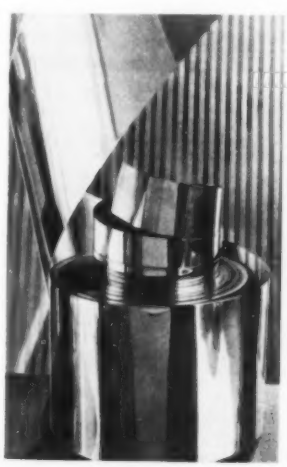
The second type, coated with commercially pure aluminum, has excellent resistance to atmospheric corrosion in outdoor applications. It can be spun or embossed, but is not suitable for drawing.

Standard methods of welding are used on both types, but techniques must be adapted to the properties of the material. The microstructure of these aluminized steels was discussed in the September issue of *Metal Progress*, p. 73.



TV Cabinet Made of Vinyl-Covered Steel

Terne-coated sheets are now produced in gages 16 through 30 with a carbon-steel base in the same grades as most other coated products—commercial, drawing quality and special killed. The material is useful in the manufacture of electronic parts because the lead-tin coating (containing 2 to 25% Sn) is easily soldered. It is difficult to spot weld but under properly controlled conditions it can be done.



Chromium-Plated Steel Strip

Joint for Folding Ruler Uses Brass-Coated Steel

Organic Coatings

Applied to steel, aluminum, and many other metals, the organic coatings, listed in the M-P Fact Sheet, are of three types: polyvinyl chloride film laminates; roller, spray, or flow coated paint surfaces and liquid plastic coatings, such as organosols or plastisols, which are embossed while the plastic material is still hot.

Tubing of Vinyl-Metal Laminate

MP **Fact Sheet**

Precoated Metals... Plated and Hot Dipped

Base Metal	Coating	Finishes	Outstanding Characteristics and Properties	Applications
Plated				
Steel	Chromium (over nickel, over copper)	Bright, satin and natural in crimps, stripes and patterns	Bright, decorative finish; corrosion and heat resistant	Electrical appliances, reflectors, hardware, trim, toys, name plates, housewares, flashlights
	Nickel (over copper)	Bright, satin and natural in crimps, strips and patterns	Retards corrosion and tarnishing. Oxidation resistant at elevated temperatures	Lighting fixtures, stove parts; radio, television and electronics parts; fan blades, flashlights, cigarette lighters
	Copper	Bright, satin and natural in crimps, stripes and patterns	Strong, low-cost substitute material. Minimizes atmosphere corrosion. Base for further plating; and also for tinning, soldering, brazing	Jewelry accessories, lamp trim and shades, control knob inserts, reflectors, buckles, handbag and luggage hardware; wall clocks, trays, coasters, curtain rods, dispensers, light fixture parts; cymbals, door knobs, display stands
	Brass	Bright, satin and natural in crimps, stripes and patterns	Decorative; strong, heat-resistant material. Low-cost substitute for expensive alloys	
	Bronze (simulated)	Bright, satin and natural in crimps, stripes and patterns	Decorative; strong, heat-resistant material. Low-cost substitute for more expensive alloys	
	Zinc	As-plated Phosphated	Long life; strong, low-cost base metal; corrosion resistant; easy to fabricate. Dense, peel-proof coating (no spangle). Phosphated surface is excellent paint base	Metal siding, mobile homes, garage doors, auto parts, dry-wall moldings and hardware; lawn furniture, flexible rulers and metal hose; refrigerator parts, oil cans, sliding door tracks, lighting fixtures, screen frames, fasteners, partitions, and vending machines
	Tin	As-plated Fused	Excellent coating adherence and resistance to chemicals, foods, and atmosphere. Good solderability and paint base; excellent formability	Cans for food products and oil; kitchenware, soldered parts, toys, detergent cans, frozen dinner trays. Other roll-formed or drawn parts which may be lithographed before forming
	Lead	Natural	Improved resistance to atmospheric and chemical corrosion	Roofing and flashing. Battery parts, and applications involving sulfuric acid
Brass	Nickel Chromium (over nickel)	Bright and satin in crimps, stripes and patterns	Durable, smooth finish; easily worked; decorative; atmosphere resistant	Lighting and fireplace fixtures; door and lock hardware; rolled moldings, housewares and trim; auto specialty items, electrical devices, and reflectors
Zinc	Nickel Chromium (over nickel)	Bright and satin in crimps, stripes and patterns	Flexible, easily worked white base metal	Auto accessories and trim; toys, name plates, and reflectors
	Brass, copper or bronze	Bright and satin in crimps, stripes and patterns	Easily worked base metal; no rusting. Low-cost substitute for more expensive metal	Badges, buttons, ornaments, trim and moldings
Aluminum	Nickel Chromium	Bright and satin in crimps, stripes and patterns	Lightweight, inexpensive, all white metals. Corrosion resistant, durable; no rusting	Trim for stoves and refrigerators; license plate frames, lighting fixtures
Copper	Nickel Chromium (over nickel)	Bright and satin in crimps, stripes and patterns	Freedom from season cracking; ductile; no rusting. Electrical properties good	Electrical and electronic parts; eraser disks, buttons, fryer lids, and signs
Hot Dipped				
Steel	Zinc	Spangled (free Zn) Minimum spangle (free Zn) Nonspangled (Zn alloy; post heat treated) All three may be phosphated	Corrosion resistance with good formability; good zinc adherence in all forming and drawing operations. Paint adherence generally poor unless phospated, or special primer paint used	Automobile, bus and truck bodies and parts; barns, boat hulls, farm equipment, filing cabinets, signs, garage doors, gutters, roofing, and siding; telephone booths, vending machines, transformers, awnings, furniture, household appliances, heating and ventilating equipment
	Aluminum	I—Al-Si coating Regular (matte) or extra smooth (temper rolled) (standard thickness coating, ½ oz./ft.² total, both sides)	Corrosion and heat resistant up to 1250° F.; good heat reflectivity. Strong, formable and can be welded. Not for outdoor use	Auto mufflers and tailpipes, furnaces, ranges, water heaters, industrial ovens, and incinerators
		II—Commercially pure Al coating Regular (matte) (1 oz./ft.² total, both sides)	Resistance to atmospheric corrosion results in long life. Not suitable for drawing operations; can be welded. Not for applications above 900° F.	Building products, outdoor lighting fixtures, agricultural implements, acoustical tile, cabinets, ceiling panels, interior curtain walls, industrial ductwork, and screen frames
	Tin	Natural	Improved resistance to atmospheric and chemical corrosion; nontoxic; base for soldering; reduced tool wear in forming; good paint base	Household utensils, toys, food containers, and closures
	Lead-tin (Terne)	Satin and natural	Excellent formability; corrosion resistant; easy solderability. Good base for exterior paints	Gasoline tanks, motor housings, radio and TV condenser cans, oil filters, oil cans, gaskets, cigarette-lighter housings (auto); electronic parts

MP **Fact Sheet**

Precoated Metals . . . Laminated and Organic Finishes

Base Metal*	Coating	Finishes	Outstanding Characteristics and Properties	Applications
Carbon steel	Laminated Vinyls	Unlimited choice of colors, textures and patterns	Decorative; resistant to chemicals, weather, heat, abrasion. Acoustical and electrical properties. Good formability; strong base metal	Television and radio cabinets, camera shells, home and office furniture, air conditioning and dehumidifier equipment, kitchen canisters, auto trim, home appliances, business machines, mobile homes, boats, wardrobes, trays, decorative tiling, wall panels, luggage, sign boards. Truck, bus and railroad car interiors
	Painted Vinyls Alkyds Epoxys Acrylics Cellulose lacquer	Complete range of colors in high gloss to dull finish. Lithographed patterns and simulated textures available	All five coatings are decorative and atmosphere resistant. VINYLS have best formability; the tough, flexible coat resists damage during fabrication. They have lower solids content and reduced hiding power but good exterior durability. ALKYDS have improved hiding power and heat resistance (to 350° F.); are economical but have poor fabricating properties. Formability of EPOXYS is good; coatings retain color well and have excellent chemical resistance. ACRYLICS display good stain and abrasion resistance; the hard film provides good exterior durability. A CELLULOSE LACQUER coating shows good resistance to outdoor exposure	Interior and exterior architectural uses, toys and auto trim; venetian blinds, furniture, appliances, roof decking, containers, closures, awnings, door paneling, storm windows, gaskets, shelving, aerosol tops, oil filters, baseboard heating units, auxiliary farm structures, lighting fixtures, brackets, frames, buckles, reflectors, business machine components, garden tools, flashlights, outdoor paneling, gutters, downspouts
	Embossed Plastisols Organosols	Many embossed patterns, textures and colors available	Decorative, textured finishes; permits more extensive forming and deformation than paint coatings. Excellent resistance to stains, chemicals, boiling water and to abrasion	Substitute for laminates, in some instances. Automotive trim, household appliances, office equipment; doors, wall panels and other architectural uses; office furniture; railroad car and bus interiors; baseboard heaters, household furniture. Vat and tankcar linings
Stainless steel	Painted Modified acrylic and other organic coatings	Good selection of colors and textures (rolled patterns)	Decorative; strong, durable base metal assures maximum coating life; relatively expensive base metal. Excellent fabricating characteristics	Awnings, balconies, bar equipment, canopies, ceilings, column coverings, counter fronts, curtain-wall panels, domes, elevator cab doors, escalators, facades, grilles, hoods, kitchen equipment, louvers, marquees, moldings, mullions, partitions, siding, soda fountains, solar shades, spandrels, spires, subway interiors, telephone booths, towers, vault doors and linings, wall tile and window frames
Aluminum	Laminated Vinyls	Variety of patterns, textures and colors	Decorative; resistant to heat, abrasion, salt water, chemicals, oils, detergents, and weather. Good formability	Air conditioning components and systems; aircraft seats, window frames, instrument panels; bus seat backs, business machine housings, cabinet doors, cabana interiors and cases of all kinds; ceiling panels, furnishings and equipment for home, office and hospitals; house trailer interiors, kitchen cabinets, lawn furniture and luggage; machine housings, radio and television cabinets and grilles; vending machines
	Painted Acrylics Vinyls Modified alkyds Enamels Epoxys Organosols Plastisols	Wide range of colors, finishes, and textures (rolled pattern sheet)	Decorative; lightweight with good formability; heat, corrosion and weather resistant. (Same coating properties as above)	Auto and bus trim, mobile home walls and roofs, door panels, roofs, farm structures, siding, awnings, curtain walls, shutters, signs, fences, duct work, interior partitions, refrigerators, air conditioners, furniture, boats, camping and playground equipment, bottle closures, cabinets for electronic equipment, lighting fixtures, hospital and laboratory equipment, textile machinery, and vending machines

*Brass, zinc and magnesium are also precoated.

Vinyl-Metal Laminates

What properties of vinyl make it a desirable material for coating metals? Vinyl is tough and resistant to chemicals, abrasion, and the weather. It provides an endless variety of designs, textures, patterns and color combinations, as well as heat-insulating and noise-reducing characteristics. The base metal is strong and the composite material can be readily fabricated without harming the vinyl coating. Easily withstanding an elongation of 30%, the composite sheet can be sheared, slit, punched, crimped, stamped, drilled, bent, drawn, roll formed, and riveted. All these operations can be performed on standard fabricating equipment.

The material can be welded; however, since vinyl is an insulator, current flow must be controlled from the metal side. Four basic techniques are successful: Graham stud welding; projection welding by capacitor discharge; spring-loaded electrode welding; and magnetic-force welding.

A vinyl-coated metal can withstand temperatures as high as 190° F. continuously without loss of color, texture or adhesion. It softens at about 250° F., chars at 400° F., but will not support combustion if properly compounded. Vinyl-coated metals are produced in mill widths up to 54 in., composite thicknesses up to 0.080 in.; and base-metal tempers ranging from soft to full hard.

Vinyl can be laminated to steel, aluminum and magnesium sheet as well as to tin-plated and electrogalvanized steel. Other good base materials are hot-dipped zinc-coated and aluminum-coated steel. In addition to sheet, strip, and coil, this composite material can be obtained in tubular form. Thickness, hardness, abrasion and stain resistance, pattern, texture, color, print, and finish can be specified. In many decorative applications, the fact that a vinyl laminate can be obtained in more than one color pattern is an important consideration.

Vinyl laminates on aluminum are available in widths from 1 to 54 in., composite thicknesses from 0.015 to 0.080 in., and laminate thicknesses of 8, 10, 12 or 14 mils. Standard base-metal sheet alloys – 1100, 3003, 5005, 5050, 5052, and 3105 in H 12 and H 14 tempers – can take any forming the unclad metal can withstand. The coatings are highly resistant to salt and fresh water as well as oil, grease, and household detergents.

The editors wish to acknowledge the assistance of the following in preparing this Staff Report: Aluminum Co. of America; American Nickeloid Co.; Apollo Metals Inc.; Armco Steel Corp.; Arvin Industries, Inc.; Bethlehem Steel Co.; Bradley & Vrooman Co.; Bridgeport Brass Co.; Clad-Rex Div., Simoniz Co.; Columbus Coated Fabrics Corp.; Enamelstrip Div., National Steel Corp.; B.F. Goodrich Chemical Co.; Industrial Finishes Co., Inc.; Jones & Laughlin Steel Corp.; Kaiser Aluminum & Chemical Corp.; Litho-Strip Corp.; Masland Duraleather Co.; Metal & Thermit Corp.; Midland Industrial Finishes Co.; Parker Rust Proof Co.; Pre-Finish Metals, Inc.; Poloron Products, Inc.; Republic Steel Corp.; Reynolds Metals Co.; Sharon Steel Corp.; Sherwin-Williams Co.; Schwayder Bros., Inc.; Thomas Strip Steel Div., Pittsburgh Steel Co.; U. S. Steel Corp.; Waldron-Hartig Div., Midland-Ross Corp.; Washington Steel Corp.; Weirton Steel Co.

Prepainted Metal

As listed in the M-P Fact Sheet, five types of paint are available to meet a variety of specific coating requirements. Equally as important as coating selection is the choice of surface treatment prior to painting. The treatment increases corrosion resistance and improves paint adhesion for a longer-lasting finish.

In aluminum, standard prepainted stock is supplied in alloys 1100, 3003, 3004, 5005, 5050 and 5052 and in thicknesses and widths up to 0.063 in. and 60 in., respectively. Painted on one or both sides with an acrylic, vinyl, or modified alkyd-vinyl coating, the prefinished strip combines the inherent advantages of aluminum – light weight and corrosion resistance – with wide color selection and lasting beauty. A surface texture can also be rolled into the prepainted sheet.

In precoating steel, a variety of formulations can be applied to coils of cold-rolled, galvanized, or tinned carbon-steel sheet. Prepainted steel, available in any color, comes in at least five coating arrangements: same color both sides; different color each side; color one side, clear coating on reverse; full color one side with wash coat on reverse; and full color one side and tinplate on reverse.

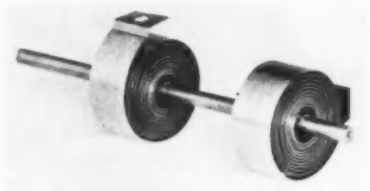
In addition to the many production advantages already noted for other finished materials, prepainted coatings function, to some extent, as a lubricant that protects both the die and the finish of *(Continued on p. 156)*

What Metal Shall I Use . . .

for Resistance-Welded Thermostats?

*By RAYMOND M. SEARS**

To be usable in temperature-controlling devices, bimetallic thermostats must often be welded to other materials. This article discusses the various types of materials to which the high and low-expansion metals can be welded. (K3; SGA-a)



. . . for Watt and Demand Meter

. . . for Space Heater

. . . for Room Thermostat

. . . for Automatic Toaster

. . . for Time Delay Relay

. . . for Motor Protector-Starting Relay

BOTH MANUFACTURE AND APPLICATION of metals and alloys for thermostats are highly specialized activities. As a consequence, engineers must constantly gather knowledge of thermostat metals and laws governing their action, along with information concerning the fabrication of parts and assemblies. For example, to unite electrical contacts, pigtails, brackets, shafts, dial pointers, and other components of fabricated parts design engineers need information concerning the weldability of thermostat metals.

Before discussing details, it should be stated that many metals, similar or dissimilar, may be welded satisfactorily even though their bond strengths may vary considerably. Thus, the weldabilities as expressed in the Fact Sheet are intended to be used only as a guide.

Procedures Prior to Welding

Four variables affect the production of good resistance welds in combinations of similar and dissimilar metals. They are: *(a)* current settings, pressure and welding time; *(b)* rela-

*Senior Engineer, Thermostat Metal Dept., Metals & Control Inc., a division of Texas Instruments Inc., Attleboro, Mass.

M P Fact Sheet

Metals for Resistance-Welded Thermostats

Compositions of High and Low-Expansion Sides, %	Welding Characteristics
1 High: 61.5 Cu, 38.5 Zn	Readily welded over a wide range of conditions. Best welds made between alloys that will form intermediate phases (brasses containing 25 to 40% Zn and Monel, for example). Good welds are obtained on phosphor bronze, silicon bronze, nickel silver, and cupronickel. Fair welds are produced on nickel, nickel alloys, and mild steel.
Low: Invar (64 Fe, 36 Ni)	Can be welded to most ferrous materials, nickel and nickel-base alloys. Welds are normally excellent to good.
2 High: 75 Fe, 22 Ni, 3 Cr	Can be welded to most ferrous materials, nickel and its alloys. Good to very good welds are normally produced.
Low: Invar (Fe; 36–42 Ni)	Nickel and an alloy of 98 Cu, 2 Ag sheet are used in different thicknesses to make a series of thermostats with varying resistivities. Higher currents are normally employed as the ratio of nickel or 98 Cu, 2 Ag alloy is increased.
3 High: 79 Fe, 19 Ni, 2 Cr	Same as high-expansion alloy 2.
Low: Invar (Fe; 36–42 Ni)	Same as low-expansion alloy 1.
4 High: 72 Fe, 14 Ni, 9 Mn, 5 Al	Weldability is slightly less than that of high-expansion alloy 2; electrode pressures are higher and currents are lower.
Low: Invar (64 Fe, 36 Ni)	As above for weldability.
5 High: 66.5 Fe, 25.0 Ni, 8.5 Cr	Classed with high-expansion alloy for weldability except that electrode pressures are higher and currents are lower.
Low: Invar (64 Fe, 36 Ni)	As above for weldability.
6 High: 70.5 Fe, 18.0 Ni, 11.5 Cr	Classed with high-expansion alloy 2 for weldability.
Low: Invar (Fe; 36–42 Ni) or Type 430 stainless	Classed with low-expansion alloy 1 for weldability except that slightly higher currents are used for Type 430.
7 High: 80.5 Fe, 14.0 Ni, 5.0 Mn, 0.5 C	Classed with high-expansion alloy 2 for weldability.
Low: Invar (64 Fe, 36 Ni)	As above for weldability.
8 High: Silicon bronze (98.5 Cu, 1.5 Si)	Classed with high-expansion alloy 1 for weldability.
Low: Invar (64 Fe, 36 Ni) or Type 430 stainless	Classed with low-expansion alloys listed in 6.
9 High: Pure nickel	Can be welded to most iron and nickel-base alloys. It can be welded to copper and copper alloys such as brasses with up to 40% Zn, phosphor bronze, silicon bronze, and cupronickel.
Low: Invar (64 Fe, 36 Ni)	As above for weldability.
10 High: 72 Mn, 18 Cu, 10 Ni	Can be welded to iron and nickel-base alloys; good to fair welds result depending on application. "Flashing" of weld metal can be reduced by decreasing weld currents and increasing times and electrode pressures. Material should be cleaned before welding.
Low: Invar (64 Fe, 36 Ni)	As above for weldability.
11 High: "B" Monel (66.5 Ni, 31.0 Cu, 1.5 Fe, 1.0 Mn)	Can be readily welded to brasses containing up to 40% Zn, nickel alloys, phosphor bronze, and silicon bronze. Good to fair welds are also produced on iron-base alloys.
Low: Invar (60 Fe, 40 Ni)	As above for weldability.

tive electrical and thermal conductivities between the two metals; *(c)* plastic range; and *(d)* relative thickness or physical size. For each welding application, all factors must be studied as a whole.

Fundamentally, welding should be considered as a metallurgical process. In this practical approach, the engineer tries to obtain a balanced heat effect, if possible, before the design of each component is definitely fixed. He also attempts to assure reproducibility of good welds by providing the welder with the greatest possible degree of precise control.

A welding projection† on one of the components to be joined will also aid in obtaining a better heat balance in difficult-to-weld combinations of metals *(Continued on p. 158)*

†This is a local raised area which acts to concentrate the current used in making a resistance weld.

FOR ROLLING CONTACT UP TO 900° F.

3 NEW LOW ALLOY TIMKEN® STEELS

To meet the new demands of defense and industry the Timken Company has developed three new steels for parts that must withstand rolling contact at high temperatures. The three steels—Timken TBS 600, CBS 600 and TBS 1000 are low alloy steels ideally suited for applications such as bearings, gears and cams. They are exceptionally clean and dimensionally stable and their heat treatment is very similar to other conventional alloy steels. Their alloy content and simple processing make them economical both in price and fabrication. All three are available in bars, billets and tubing.

TBS 600

This through hardening steel has a recovered hardness of 59 Rockwell C measured at room temperature, after holding 500 hours at 600° F. Hot hardness at 600° F. is 53/55 Rockwell C—extremely high for a low alloy steel.

CBS 600

This carburizing steel has a hot hardness of 56 Rockwell C and a recovered hardness of 61 after 600 hours at 600° F. at the 1% carbon level. Corresponding hardness for the core is 55 to 58 Rockwell C.

TBS 1000

This low alloy steel was developed for continuous operation at 900° F. and up to 1000° F. for short periods. Has a hot hardness of 54 Rockwell C at 1000° F., a recovered hardness of 64 after 1000 hours at 900° F.

Write for the free booklet giving full descriptions of these three new Timken steels. The Timken Roller Bearing Company, Steel and Tube Div., Canton 6, O.

TIMKEN® FINE ALLOY STEEL

See us at the Metals Show, Cobo Hall, Detroit, October 23 to 27, Booth #739.

Circle 1457 on Page 48-B

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LETTERS TO THE EDITOR

Are You Becoming Obsolete?

CULVER CITY, CALIF.

Your Critical Point "Are You Becoming Obsolete?" in the July 1961 issue strikes a very tender spot. In trying to explain why it irritates me, I hope you get the idea that there aren't as many people "looking for park benches" as your writeup implies. To my mind, this article is remiss in that it does not play the other side of the record.

Let's assume, for example, that our man has a science degree from a good university, has acquired a personal library of reference books, belongs to technical societies and goes faithfully to their meetings and conventions, and attends evening classes to round out his education. What does all this get him? Does the employer do anything to recognize these things? What are the problems of the employee in applying all this voluminous knowledge? And particularly, will he be encouraged to put forth effort to continue to broaden his knowledge?

Frankly, I think someone should be looking for answers to these questions. If *Metal Progress* chastises A.S.M. members, why not criticize the managements of companies, too? If the employee does not always measure up to swiftly changing needs of the employer, there is a possibility that management was a bit shortsighted. Men will rise to meet a challenge when given the chance, but supervision should create the proper atmosphere.

An example of how short-range planning by management affects professional people is found in some of the industries doing defense work. Though our federal government requires bidders for defense contracts to show professional capability, this does not always help the professional status of the individual. Even if defense contracts do not materialize, the companies cannot afford to release too many technical people. As a result our A.S.M. member finds himself in a job with very little challenge or incentive.

It seems to me, also, that employers as a rule do not consider technical people as good material to build up for management positions. In other words, we're off the main stream. Because of the seeming lack of confidence in the ability of technical people to learn additional responsibilities, about the most an engineer can hope to achieve is a position in middle management.

As a side point, do you notice the advertisements that companies often publish showing their modern concept of scientific advancement? In typical illustrations, a man wearing a laboratory apron is posed at a bench covered with a complicated glassware setup. More often than not, he is operating the equipment incorrectly.

As a final remark, your usage of the phrase "running twice as fast as that" to get somewhere really puts the average engineer on a treadmill. Could it be that the "new frontier" at A.S.M. headquarters does not have the same respect for the A.S.M. member that the old frontier had? Heaven help us if this is true. My membership dates from 1940, and in all this time I don't recall reading anything published by the Society that has rubbed me the wrong way as much as this article. In my opinion, metallurgists and technical people need someone to champion their cause, not to tear it down. The general tone of your article seems to imply that the increase in scientific information has caused a state of utter confusion with which we engineers cannot cope. We're all ready for the "park bench"? Roll out the hearse!

KENNETH E. VANDAVEER

UNIVERSITY PARK, PA.

In the July 1961 issue you ask technical men the daring question: "Are You Becoming Obsolete?" The answer is simple: We all are obsolete and always will be. Though some realize it more than others, others live a life of the stone age. In fact, there seems to be less and less learning from generation to generation. Specialization starts sooner, and curricula can be finished in a shorter time. The idea of studying and obtaining knowledge for its own sake seems to have become obsolete.

Most people would go along with your statement that the billions of money spent by research and development organizations and the many hours dedicated to such work have resulted in a "staggering increase of knowledge". You might scare them with the idea that the knowledge they need for their profession doubles every so many years, and that they leave a trail of "obsolete knowledge" behind them. However, in rebuttal, facts and figures may change during the years, but basic knowledge cannot be obsolete. Nor can it be measured in billions of dollars, manpower years or percentages. While the number of words printed and dollars spent rise to astronomical figures, the amount of new and useful knowledge is very small indeed. There is an increasingly great danger of losing the needle of knowledge in the haystack of printed matter.

KARL M. WEIGERT
Assistant Professor
Pennsylvania State University

EDITORS' NOTE—In publishing the Critical Point "Are You Becoming Obsolete?", we meant only to stress that the professional development of a technical man was largely dependent upon his own actions, and that he must strive to keep abreast of his field. It might be added that management surely bears a responsibility in making the fullest use of its technical talent if only for its own benefit. And in this critical period of the nation's history, it is even more important that each and every technical man be employed to his extreme capability. Since this "Critical Point" seems to have hit a nerve, we would be interested in further comments.

CONTINUOUS CASE-HARDENING or CLEAN HARDENING in the VERSATILE

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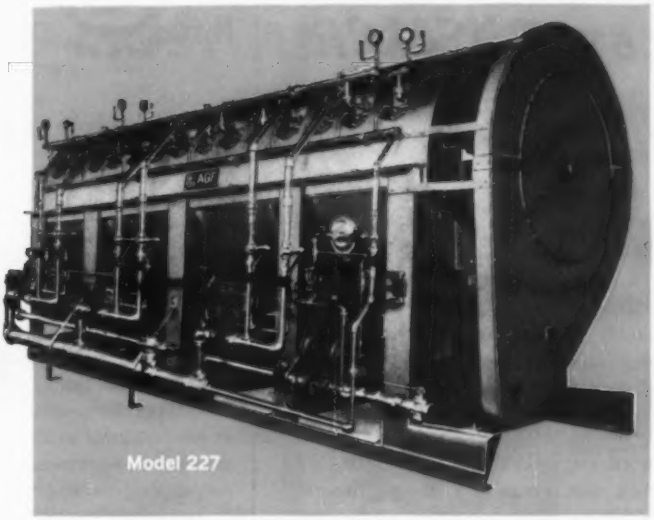

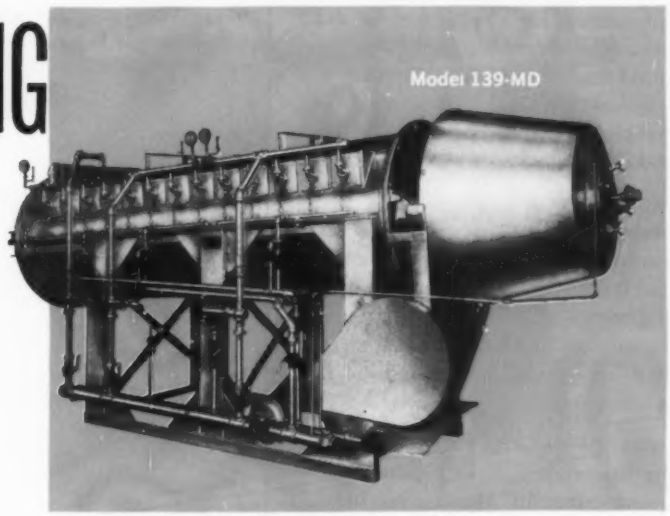

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Circle 1458 on page 48-B

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Nitriding . . .

(*Continued from p.* 83)

detrimental effects in later nitriding operations. The ability to develop and retain high core strength and toughness, even with long nitriding cycles designed to give the maximum case depth, is quite important since it indicates that higher crushing loads may be sustained. Illustrative of this is the use of nitrided Vascojet 1000 in power gears operating under Hertz loads of 150,000 to 200,00 psi. for several hundred hours at temperatures to 550° F. Figure 1 shows an experimental gearbox incorporating these gears.

As with other alloy steels, testing has demonstrated that maximum intrinsic surface hardness of H11 steel varies with the degree of tempering (and, therefore, with the core hardness) because of the effects of alloy removal by carbide precipitation. For example, further work in our laboratories has shown that an extremely high case hardness (Rockwell C-75 by conversion) results when the carbon content of H11 is decreased from 0.4 to 0.2%, even when nitriding temperatures as high as 1020° F. are employed for 70 hr. With this lower carbon grade, core hardness may be maintained as high as Rockwell C-50.

Higher-Alloy Grades

Many high-alloy steels such as the M and T types of tool steels can be nitrided to high hardness levels. However, the great amounts of nitride-forming elements result in heavy surface area reaction which interferes with nitrogen diffusion capabilities. Because of this, case depths of only 0.010 in. (max.) are produced by treatments of 30 to 40 hr. However, a case of 0.0005 to 0.0010 in., useful and adequate for such applications as drawing dies, tools and the like, may be attained in about 1 hr.

Because of their high chromium and nickel contents, the Type 300 stainless steels are also difficult to nitride; the alloy content hampers development of deep cases. This class of material may be considered for applications involving sliding contact wear where mechanical strength is not of prime importance. High hardness penetration of a few thousandths of an inch is usually adequate and typical of that produced in a cycle time of 20 hr. Deeper cases may be produced, but these are normally brittle.

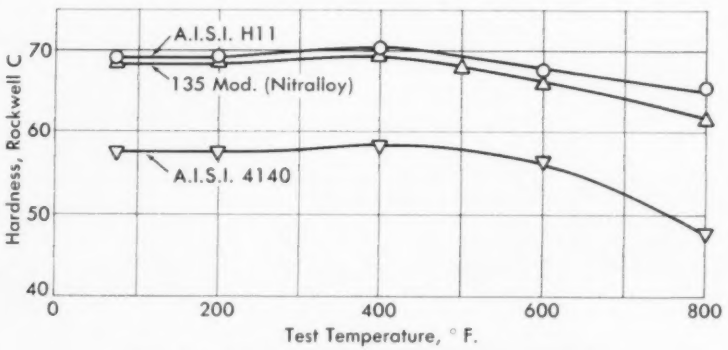

Fig. 2 – Hot Hardness Tests for Three Nitrided Steels. Note high resistance to softening at elevated temperatures. All hardness readings are converted from Rockwell 15-N; samples were held 30 min. at temperature before testing

Wear Properties and Temperature

High temperature is one of the many problems encountered in dealing with wear phenomena of metal surfaces in intimate moving contact. Very simply, high temperatures can create metallurgical instabilities in unprotected surfaces, and decrease hardness and strength. Often, this results in high rates of wear and early failure through scoring, seizure, or galling.

High temperatures may arise from friction alone or through high ambient temperatures. The problem of high wear is particularly difficult to

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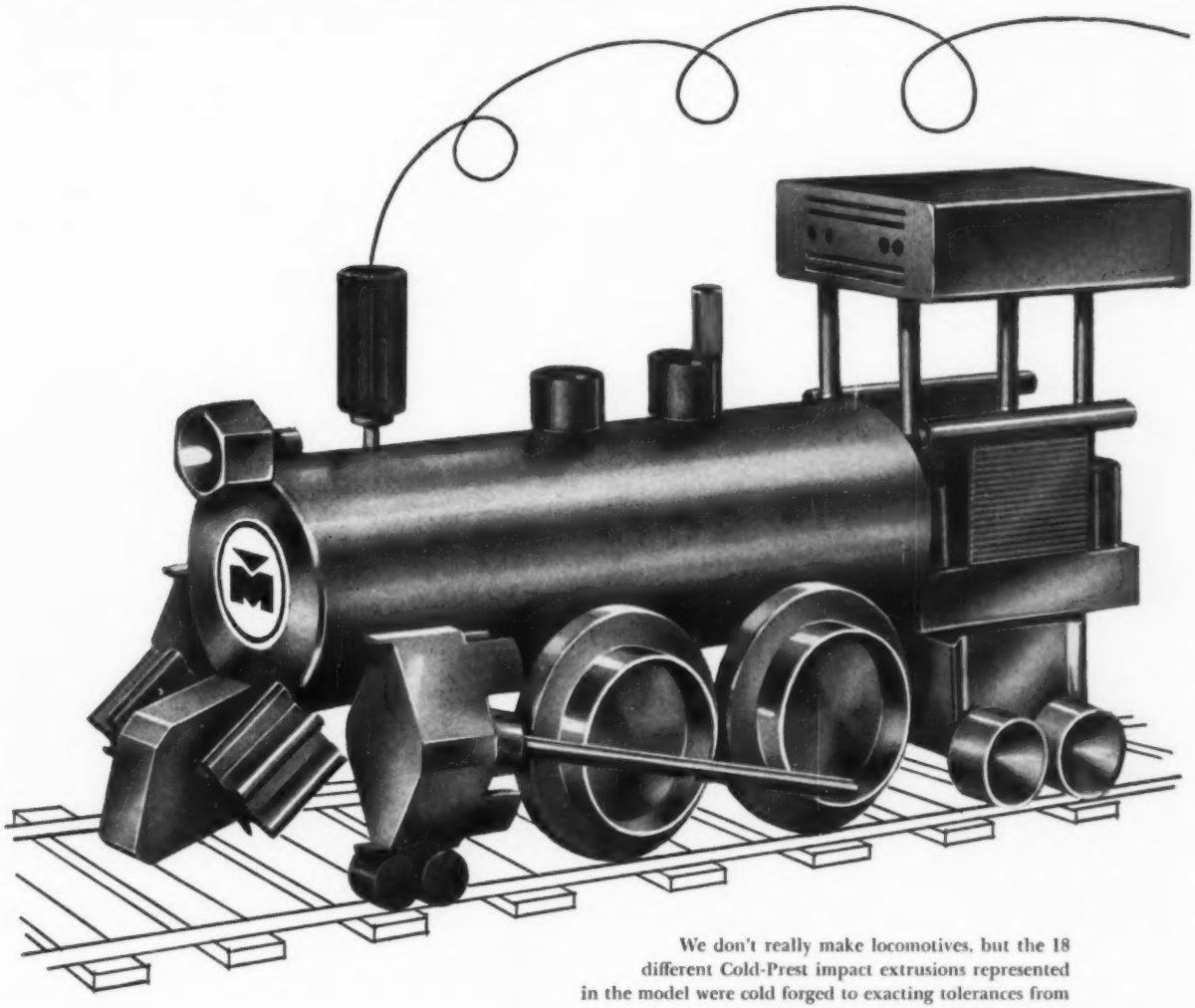

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Circle 1459 on page 48-B

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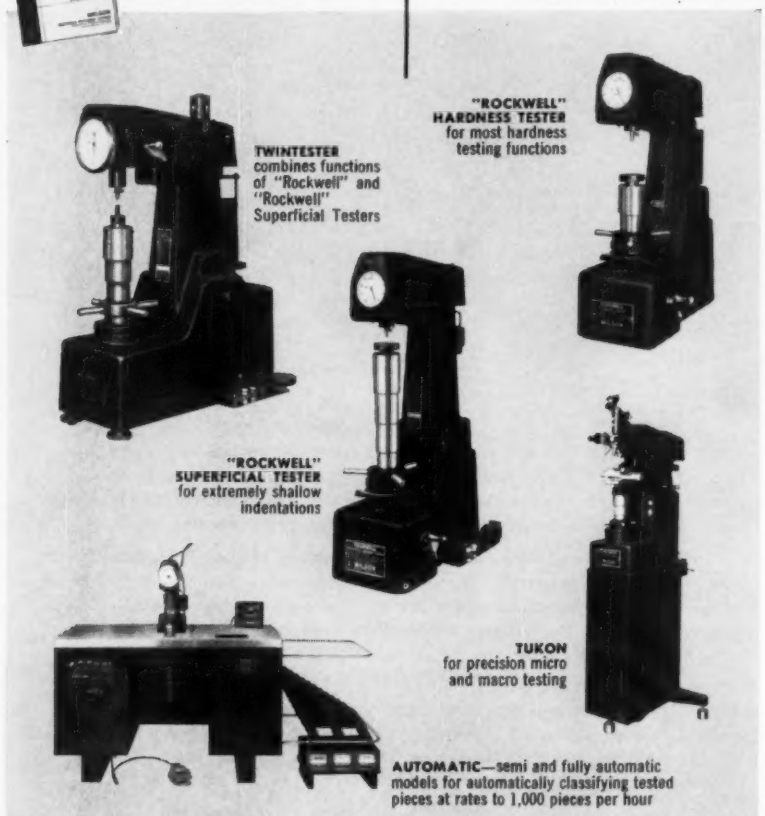
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Circle 1460 on page 48-B

Nitriding . . .

solve in the aircraft industry, because rising operating temperatures have limited the effectiveness of lubricants, and, therefore, greater intrinsic wear resistance of the materials employed is required.

Two tests which can be used to screen materials for wear applications might be mentioned. The first is the hot-hardness test which is widely used in evaluating materials for sliding or rolling contact wear in gears, seals, pistons and bearings. Results of such tests with nitrided materials, demonstrating hardness retention and stability through 700° F., are shown in Fig. 2. Tests showing how hardness depths vary with nitriding are shown in Fig. 3.

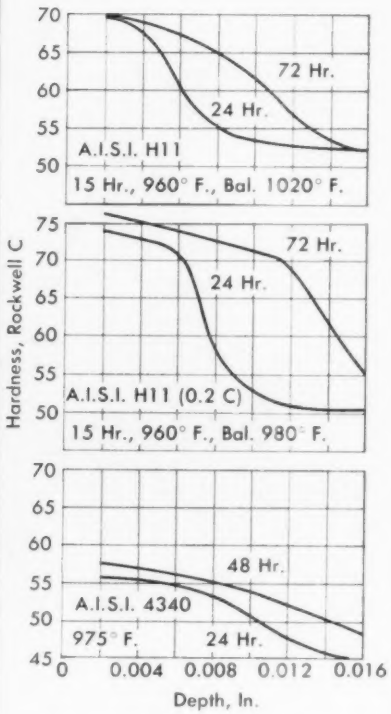
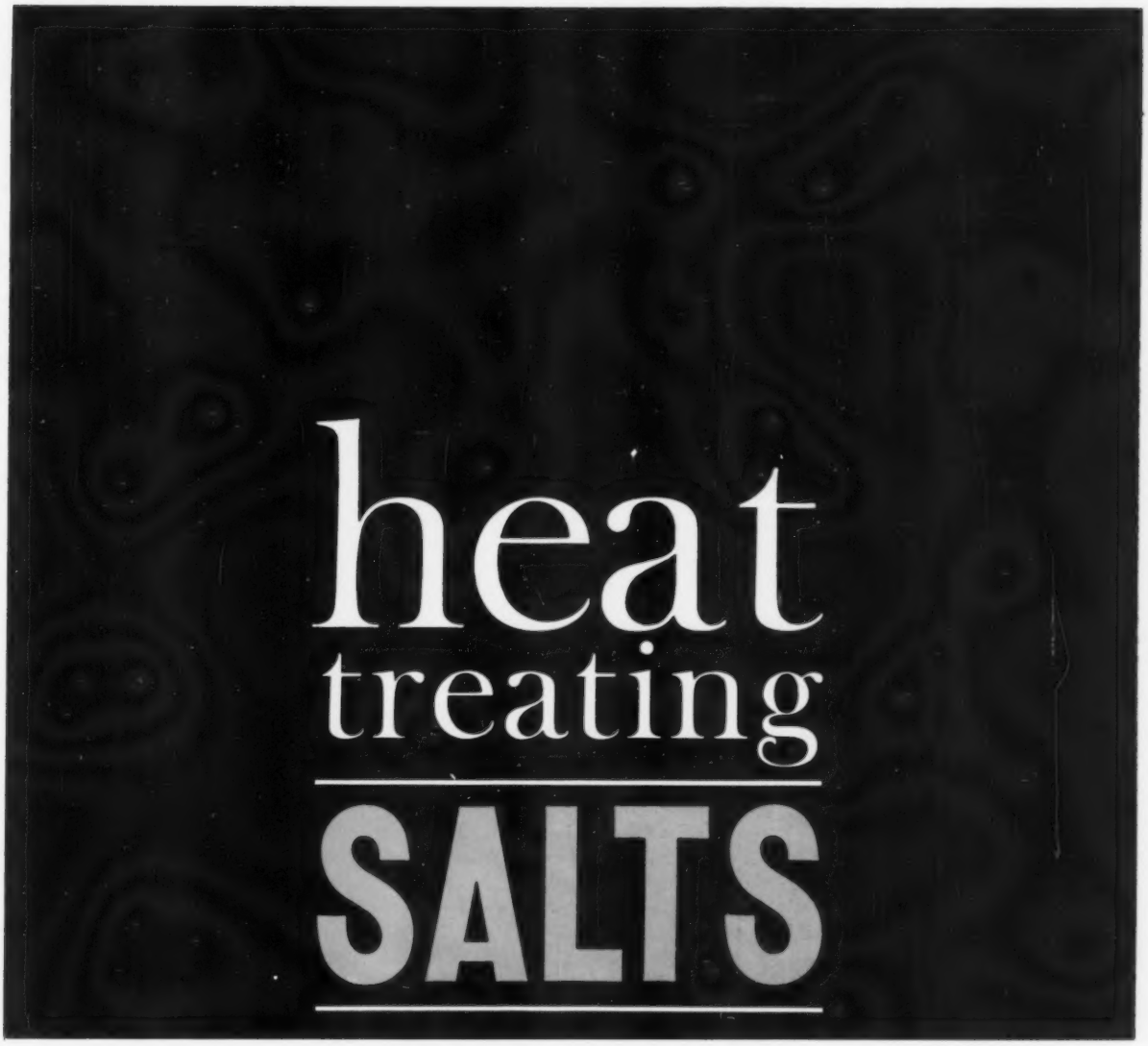


Fig. 3—Variation in Hardness With Depth Below Surface as a Function of Nitriding Time. Specific nitriding cycles for three A.I.S.I. grades are listed on the charts; Rockwell C hardnesses are converted from Tukon readings made with a 500 g. load

A second bench test, directly demonstrating resistance to sliding wear, is used in our laboratories. The apparatus, a Hohman A-6 wear tester, provides control of loading, speed,



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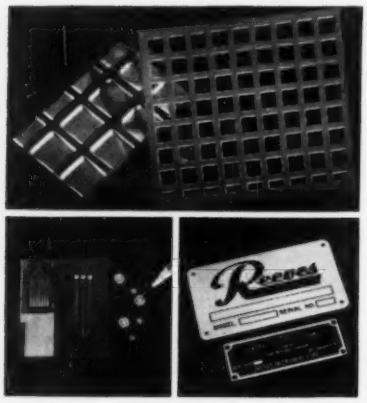

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Circle 1462 on page 48-B

Nitriding . . .

lubricant, temperature, and cover atmosphere. Test pieces of materials which take the form of "rub-shoes" are loaded through a system of weights and levers against the second test element, a driven rotating "ring". Wear is evaluated as a function of test conditions employed by measurement of static and kinetic coefficients of friction, rub-shoe wear scar, change in the surface finish of shoe and ring, and an arbitrary scoring or "pickup" rating scale.

Bearings . . .

(Continued from p. 103)

of the soft bearing alloy, the cast bearing has the higher coefficient of friction. The range in values shown represents chatter, caused by a "stick-slip" or instantaneous seizure mechanism. The use of these alloys is extremely limited above 550° F., as evidenced by the sudden increase in friction. Furthermore, the alloy is considered unusable in the fluid because of metal corrosion rather than friction.

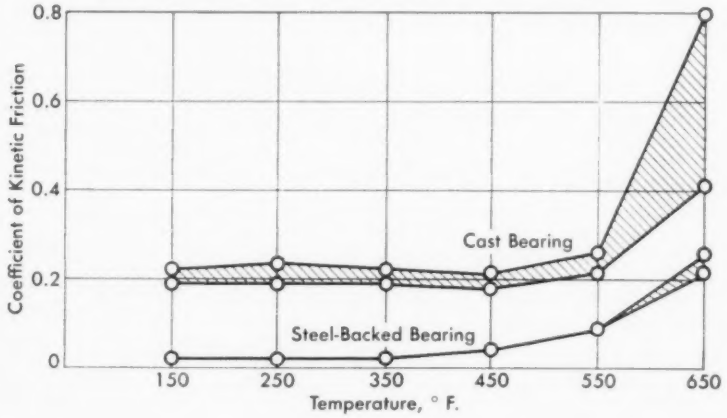
The effect of increasing chromium content on the bearing properties of bronzes is illustrated in Fig. 2. Comparisons between a 4% Cr tool steel (A.I.S.I. M50), a 5% Cr steel (Halmo – 0.60 C, 1.00 Si, 5.00 Cr, 5.25 Mo, 0.65 V) and chromium plate are shown. This illustrates the effects of surface conditions and alloying. The higher the chromium content, the less surface interaction, and the lower the coefficient of friction. Chromium does not alloy as readily with copper as does iron.

Figure 3 represents some data for the silver alloys listed in the Fact Sheet. The rapid rise in friction with temperature of coin silver makes it unusable with steel in this fluid. Though the coefficient of friction of the sintered tungsten-silver alloy is higher than that for pure silver or silver-lead, the alloy is also harder and stronger. Thus, a higher PV rating is still obtained (see Fact Sheet for comparative PV ratings).

The data show that silver alloys are very useful as plain bearings in intermediate temperature ranges, 400 to 700° F. Sintered alloys which contain silver have also been used up to 1000° F. Though mechanical weakness of silver limits the application of heavy coatings drastically, alloys designed to provide a hard, strong matrix containing dispersed silver (such as those of tungsten or nickel silver) can provide the necessary backing. However, machining and assembling these materials represents something of a problem because of the hardness and brittleness of the matrix.

The cermets and ceramics used at extreme temperature are very sensitive to contamination by the fluid. As the temperatures increase and successively harder materials are applied as plain bearings, designers,

Fig. 1 – Coefficient of Kinetic Friction as a Function of Temperature for Two Types of Bearings. As is evident, the cast bearing has a higher coefficient than the 0.030-in. bearing coat backed with steel. In each instance, the bearing material was bronze containing 10% Zn and 10% Pb; tests were run in chlorinated silicone fluid



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Circle 1464 on page 48-E

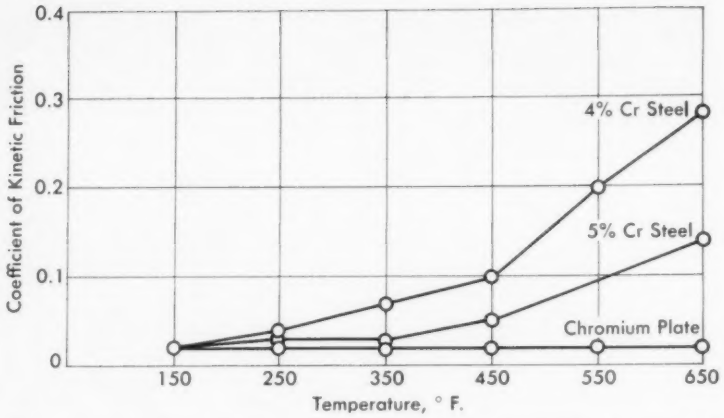


Fig. 2 – Coefficient of Kinetic Friction of Two Chromium-Containing Steels (M50, Top Curve, and Halmo, Middle Curve) and Chromium-Plated Bronze as a Function of Temperature. With increasing chromium, the coefficient of friction drops; this is probably due to the decrease in surface interaction since chromium alloys less readily with copper than does iron

fabricators, and users will need more care in maintaining the cleanliness of the system to exclude contaminants larger than the clearances.

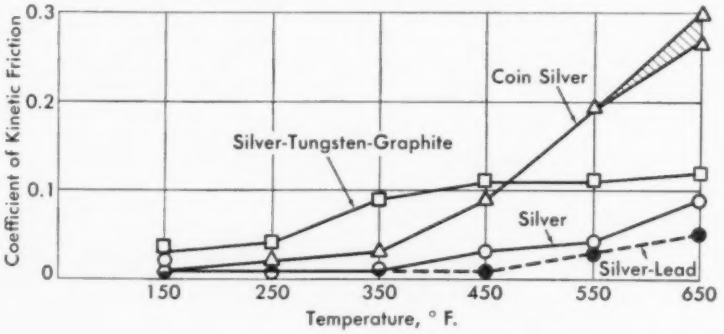
Rolling Contact Bearings and Gears

The major criterion governing the selection of materials for rolling contact bearings and gears to be used at elevated temperature is hardness at the operating temperature. Stability is equally important. Up to 300 to 350° F., A.I.S.I. 52100 is most often used, and the 4% Cr, 4% Mo steel (M50) is very widely employed at temperatures to 600° F. In fact, the latter steel has become an industry standard. M1 tool steel may be used to about 800° F., and temperatures up to 1000° F. have been mentioned for tungsten steels (T15) and some experimental alloys. Design figures depend largely on the time-temperature-load-environment characteristics of the use.

Where corrosion resistance is needed, Type 440 C stainless can be used. However, hardness-temperature characteristics limit it to applications below about 450° F. Vanadium and molybdenum modifications of the basic Type 440, however, extend the useful range to 600° F. Temperatures in excess of 1000° F. require the use of ceramics (pyroceram, for instance) or carbides such as chromium carbide or titanium carbide.

For bearing cage materials, which may also be selected from the Fact Sheet, iron-silicon bronze, "S" Monel and "S" Inconel, with or without silver plating, are most widely used. Use of the 5% Cr die steels for re-

Fig. 3 – Coefficient of Kinetic Friction as a Function of Temperature for (1) Silver, (2) Silver-Lead, (3) Coin Silver, and (4) Silver-Tungsten-Graphite. As is apparent, coin silver is unusable above 500° F. with steel in the testing fluid (disiloxane) because of the rapid rise in coefficient of friction



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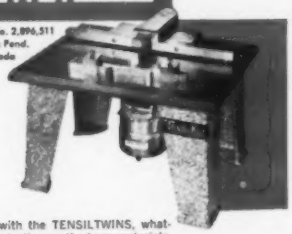

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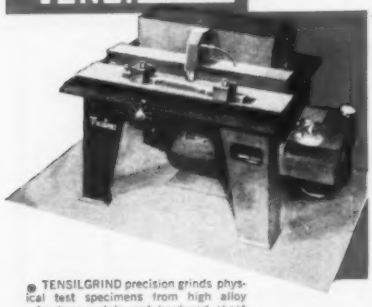

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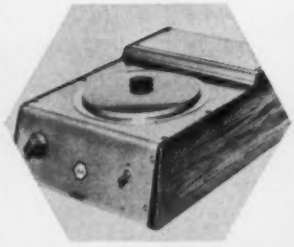

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NEUTRAL GOLD
For ELECTROPLATING
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produces an ultra pure 24 Kt satin bright deposit that is stress free; is extremely ductile and tight grained with exceptional heat and corrosion resistance. Contains NO brighteners, either organic or inorganic; NO free cyanide; NO harsh alkalis or acids; economical to operate and simple to maintain.

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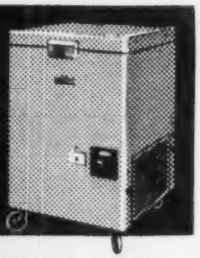
NEW SMALL PORTABLE 2 CU. FT. – 130 REFRIGERATOR
FOR TREATING SHRINKING TESTING



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Since 1934
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FOR COMPACTING POWDERED MATERIAL TEST SPECIMENS....

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- Stepped Parts

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Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

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Electronic instruments for production sorting of ferrous and non-ferrous materials and parts for variations in composition and structure.

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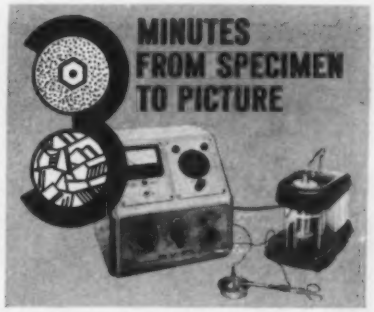

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the Gries REFLEX hardness tester covers the ENTIRE range of hardness from the softest to the very hardest. It yields standard test data by Zeiss automatic projection system—the ultimate hardness tester for research and routine inspection.

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Testing Machines Division
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Circle 47 on Page 48-B

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the QUENZINE STORY

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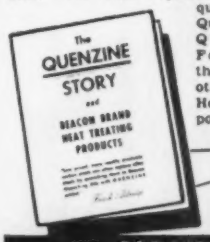

ALDRIDGE

ALDRIDGE INDUSTRIAL OILS, Inc.

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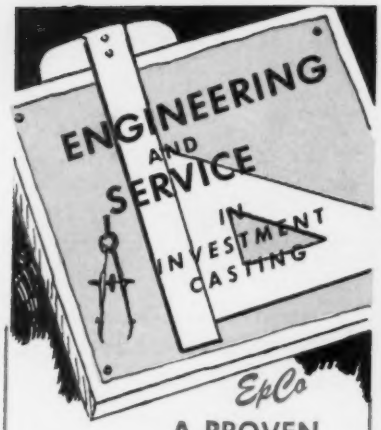
Circle 48 on Page 48-B



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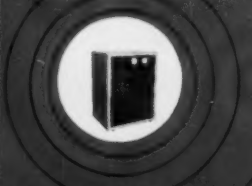

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Circle 52 on Page 48-B

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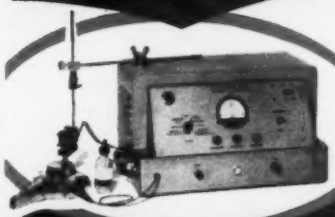

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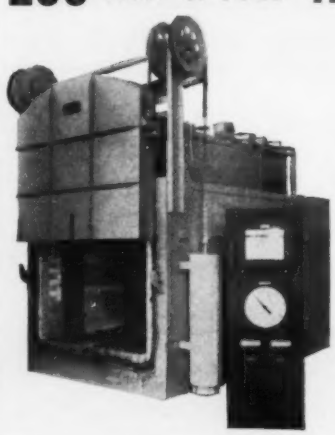
200 NEW & USED HEAT TREAT FURNACES



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We will engineer to your requirements
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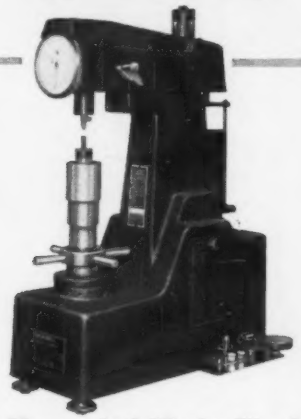
Circle 50 on Page 48-B

Wilson "Rockwell" TWINTESTER



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WILSON "ROCKWELL" HARDNESS TESTERS

Wilson Mechanical Instrument Division

ACCO

American Chain & Cable Company, Inc.

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Circle 55 on Page 48-B

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Circle 56 on Page 48-B

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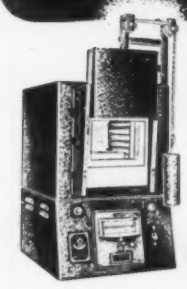
Circle 57 on Page 48-B

HUPPERT ELECTRIC FURNACES AND OVENS

for Laboratory and Plant



*For 2300°F. add $95.00 to No. 11 and No. 12, and $105.00 to No. 12A. No. 12A can be furnished for 3 phase at no additional cost. For floor model add $52.00 to above prices. No. 869 standardly supplied for 2200°F.

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- Range: 300°F. to 2000°F.
- High temperature, heavy-duty Kanthal elements
- Multi-insulation
- Counter-weighted, tight-sealing door
- Operational pilot light
- Shipped ready to operate

Model No.	Inside Dimensions			KW	Prices 220 Volt Single Phase	
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869	8"	6"	9"	4	$296.00	$480.00
11*	8"	6"	12"	4	306.00	518.00
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28 Standard Sizes

- Continuous operation to 1850°F.—intermittent to 1950°F.—for 2300°F. on special order.
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- Tight-sealing, wedge-type door.
- Multi-insulation for maximum efficiency.

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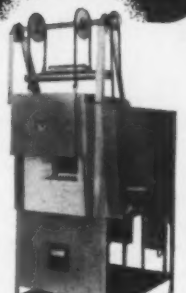

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K. H. HUPPERT CO.

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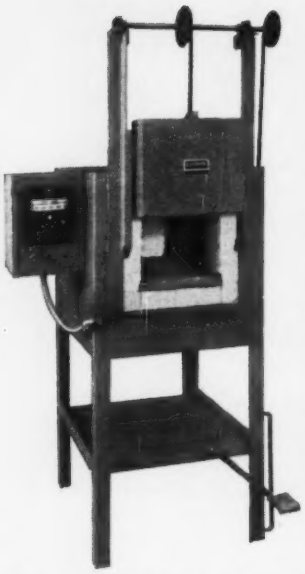
6844 Cottage Grove Ave., Chicago 37, Illinois

Request new catalog on furnaces, ovens, data, prices.

Circle 58 on Page 48-B

LUCIFER "SPACE-SAVER" COMBINATION HEAT TREATING FURNACES



Two series (8012 and 8008) of "space-saver" combination heat treating furnaces are produced by Lucifer Furnaces, Inc. Hardening, drawing or preheating, and quenching operations can be performed with one furnace. Each furnace has separate controls permitting independent operation of each unit. The 8012 series chambers operate at 2300, 2000 and 1250° F.; while the 8008 series chambers reach 2300, 2000, and 800° F. The furnaces operate on standard line voltage . . . no transformer necessary. Twenty standard low-cost models are available and each is a complete unit . . . just connect to power supply.

For information about the "space-savers", our complete line, or free engineering advice, call on . . .

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- NO CONVERSIONS OR CALCULATIONS
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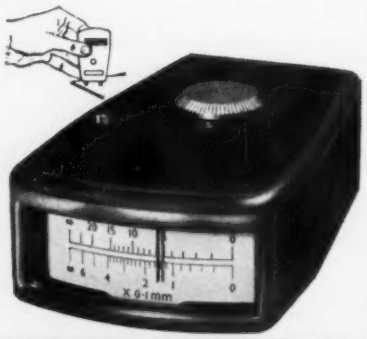
Circle 61 on Page 48-B

More than 10,000 in use:



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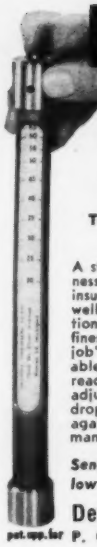

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Test Block accurate instrument only $39.50 complete

A steel ball of exact weight and hardness is dropped from an exact height, insuring a precise reading in Rockwell C scale. Ideal for spot or production checking. Used in many of the finest plants and shops. Get "on-the-job" readings **anywhere** with dependable accuracy. Easy to use, easy to read. No moving parts to get out of adjustment, even if the instrument is dropped. A one-year warranty protects against defects in materials and workmanship.

Send for one or more today at this low price. Satisfaction guaranteed.

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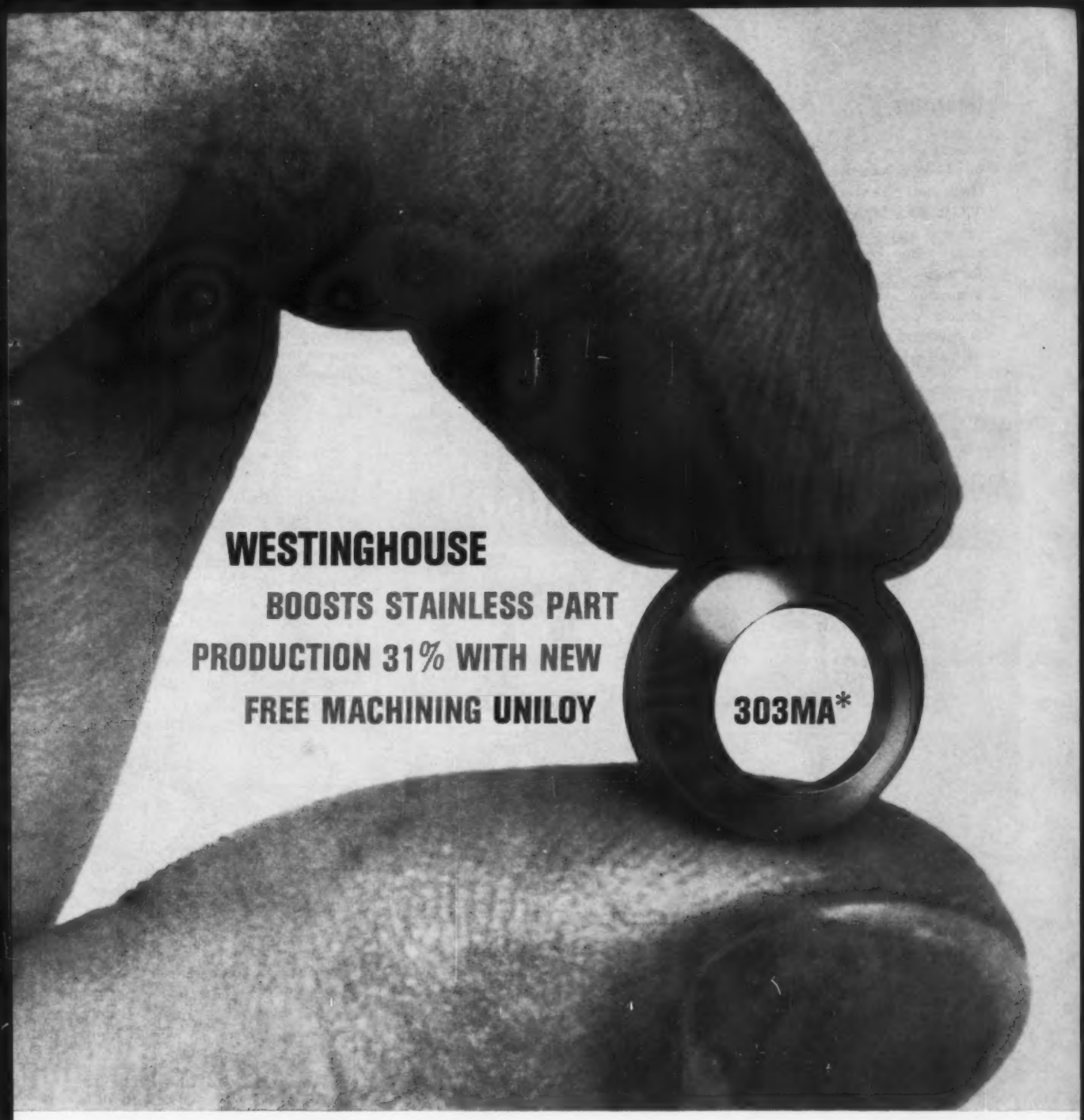
COBO HALL

October 23-27, 1961



The Westinghouse Standard Control Division at Beaver, Pa., compared New free machining Uniloy 303MA* stainless steel with regular Type 303. The part—a close tolerance spring end support for circuit breakers and control equipment—was machined from ½-inch stock. Here are the production line results:

	AISI Type 303	New Uniloy 303MA
Spindle Speed	890	1180
Surface Ft. per Min.	115	155
No. Pieces per Hour	110	144
Tool Life	Form tool sharpened 3 times every 8 hours	Form tool sharpened once every 6 hours

New Uniloy 303MA also machined cleaner and smoother to produce higher quality parts. It is now specified in all applications formerly calling for Type 303 stainless steel at this plant.

Cut *your* production costs! Order New Uniloy 303MA at your nearest Universal-Cyclops steel service center or sales office. Ask for your copy of the "Uniloy 303MA" brochure.

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EXECUTIVE OFFICES: BRIDGEVILLE, PA.

*U.S. PATENT NO. 2,900,250

STAINLESS STEELS / TOOL STEELS / HIGH TEMPERATURE AND REFRACTORY METALS

Circle 1429 on page 48-B

Bearings . . .

tainers in the 400 to 800° F. range has been reported as has the use of chromium-plated retainers.

Gears for high-temperature applications may be selected from the same group of materials employed for antifriction bearings. Ordinarily, a measure of core toughness is desirable, and a case-hardening steel is specified. Up to about 350° F., carburized 9310 or 9315 steel is used. Above this temperature, a higher chromium-molybdenum carburizing grade such as A.I.S.I. H11 may be used, or a nitriding grade, Nitralloy N or 5 Ni, 2 Al. The nitriding steels provide a higher surface hardness with a core hardness of about Rockwell C-40, but the carburizing grades are limited to a minimum core hardness of Rockwell C-50 to 55 if the lowest case hardness desired is Rockwell C-58. (More information on nitriding steels is given on p. 82.)

For applications that involve intermittent sliding velocities which are relatively slow (10 to 50 ft. per min. maximum), either molybdenum disulfide or graphite are the most common lubricants. These materials are bonded to the metal needing lubrication in films about 0.0005 in. thick, the usual bonding agent being a thermosetting resin. Since the resin is useful only up to 400° F., other binders such as metal or ceramic are needed when the operating temperature is higher. Teflon fluorocarbon can be used up to 450° F., metal up to 800° F., ceramics between 1200 to 1500° F., and glasses as high as 1800° F.

Teflon is available in a wide variety of forms impregnated with glass, graphite or metal for application as a bearing material or coating. It exhibits extremely low friction, but is limited in maximum operating speed. Above about 500° F., Teflon becomes mechanically unstable, decomposing rapidly at 750° F. to give off poisonous products. It is also subject to creep, cold flow and stress relaxation and undergoes a radical volume change (1.0 to 1.8%) at a transition temperature of 65 to 77° F.

Resin-bonded films are also widely available commercially. Metal pretreatment is of primary importance since it affects the wear life of films, but it does not radically affect the frictional properties. Several metal-bonded films are available which extend the useful range of dry films to 800 to 1000° F.

Ceramic dry films have been developed by the National Aeronautics and Space Administration in recent years. These films are a ceramic compounded from lead oxide; they show great promise for use above 1000° F.

A number of glass materials are available for lubrication at elevated temperatures. Ordinarily, these are for a one-time-only application such as metalworking, since they become brittle at low temperature.

Selecting a bearing material to be used at elevated temperature and the development of design data is often a cut-and-try procedure. Lubrication, a prime requirement, may be obtained in several ways. For example, it could be produced by a surface reaction between the working fluid and the sliding or rolling materials, by a reaction between the

4 ULTRASONIC PROBLEM BUSTERS by BRANSON

FLAW DETECTION

SONORAY® ULTRASONIC FLAW DECTECTOR

SONORAY detects and locates flaws. SONORAY measures thickness and detects metallurgical variations. • compact • portable • low cost.

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THICKNESS GAGING

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- thickness gaging from one side
- accurate to ± 0.5%
- easy to operate
- gages metal, plastics, glass
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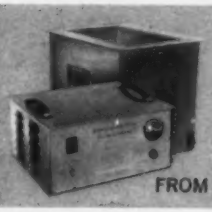

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- fully automatic for maximum efficiency
- automatically tunes itself to optimum operating frequency
- activity meter indicates cleaning effectiveness of tank

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Circle 1430 on page 48-B

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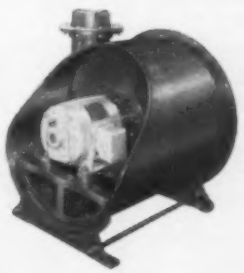

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Circle 1431 on page 48-B

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In the installation shown above, individual thermocouple wires are being checked against a platinum reference standard. The equipment consists of a:

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* *At the fixed points.*

LEEDS NORTHRUP
Instruments Automatic Controls • Furnaces

"Pioneers in Precision"

Circle 1432 on page 48-B

atmosphere and the mating materials, by applying a dry lubricant, or by using a duplex bearing structure, one phase of which is soft. In all instances, the desired effect is a surface film having a low strength or resistance in the direction of motion and a high strength in the direction of loading. In short, bearing materials for elevated temperature are selected according to their compatability with the fluid and atmosphere used, their resistance to seizure or welding with the shaft material, and their mechanical and dimensional stability.

Cryogenics . . .

(Continuer from page 115)

brittle at ambient temperature, remains relatively unchanged at low temperature. Parts normally made of cast iron, such as rotary pump bodies or the bodies of large, low-pressure valves, can thus be used at low temperature as well as at ambient. It is important, however, to make certain that thermal strains in piping, for example, do not place undue stress on such parts. Type 2 Ni-Resist, containing spheroidal graphite with 24% Ni, provides a tough, low-temperature alloy for cast parts.

Conventional fluid lubricants cannot be used between movable parts at extremely low temperatures since the lubricants freeze and prevent motion. But galling and seizing of the rubbing surfaces frequently occurs when a lubricant is not used. To avoid this, it is helpful to employ different metals for both movable members, particularly with austenitic stainless steels or aluminum alloys. There is considerable improvement, for example, if a valve stem of stainless steel operates in a bronze bonnet instead of one made of stainless steel.

If bonded graphite or a plastic is used for one member of a friction pair, it generally is superior to any metal. Plastics, however, undergo such great shrinkage in cooling to cryogenic temperatures that they bring on other problems. Filled Teflons are used to a considerable extent in this area, and Teflon-coated metal parts offer another possible solution. If liquid oxygen is present, the choice of plastics and metal for rubbing parts is further limited because high concentrations of oxygen can react violently with most organic materials and also with ferrous metals.

Soldering and Brazing

Joints in cryogenic equipment are frequently made by soldering or brazing in preference to mechanical methods, particularly if the joint is located in a vacuum chamber where a slight leak would render the entire vacuum system ineffective. Soft solder (50% Pb, 50% Sn), used primarily with copper equipment, is seldom satisfactory for leak-tight joints in high pressure systems or where the temperature rises above ambient. It is also brittle at low temperatures.

Many of the problems with soft solder are avoided by using a hard solder or silver braze. Such joints are useful, for example, in joining stainless steel to copper or its alloys. Brazes containing phosphorus, however, may be brittle. When brazing stainless steel, it is important that it be in an annealed condition. If it has been cold worked, there may be cracking and penetration of the stainless by the molten braze metal.

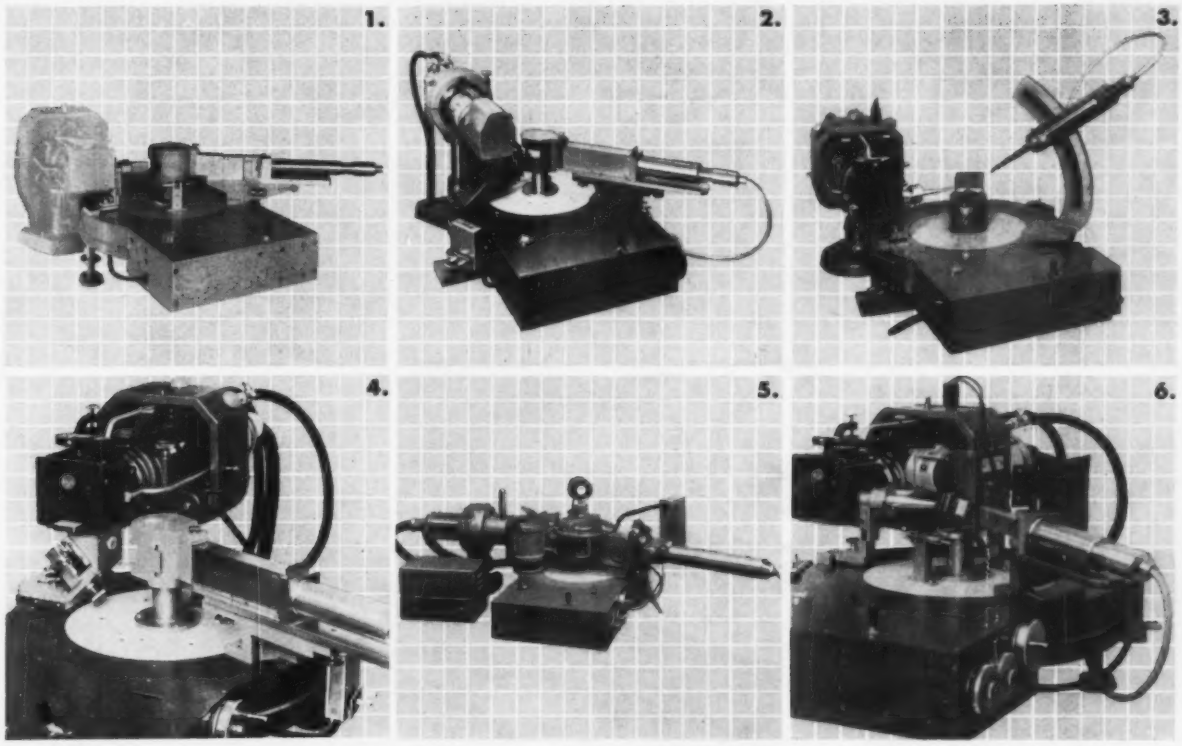
Direct brazing of an aluminum alloy to a stainless steel part results in a brittle zone in the fused metal. But considerable success has been achieved with this combination by using an intermediate member of pure silver, which is welded to the aluminum member with an aluminum-silicon alloy, and to the stainless member with a silver rod.

Welded vessels for cryogenic service are tested in the normal manner with x-rays, hydrostatic and air tests. Many cryogenic containers are insulated with vacuum and require additional tests to insure against leaks so small that they cannot be detected with normal methods, but which could cause the high vacuum to deteriorate rapidly.

The Freon leak detector is sensitive to a leak of about 1 cc. in 10 days. The newer leak detectors based on the helium mass spectrometer, however, are sensitive to a leak of 1 cc. in 300 years. Furthermore, they give quantitative data on the magnitude of the leak so that vacuum performance can be assured.

The welded vessel is tested first as a complete unit, usually by evacuating the vessel while the exterior is bathed in helium gas held in place

X-RAY DIFFRACTION AND SPECTROSCOPY



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RADIO CORPORATION OF AMERICA

Circle 1433 on Page 48-B

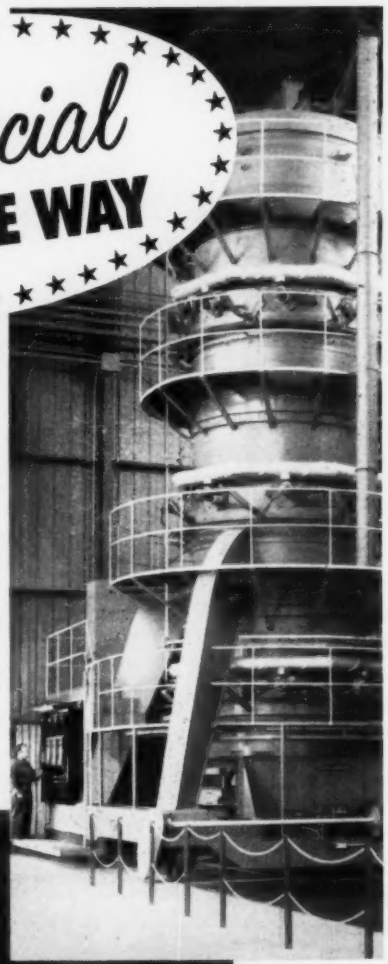
Cryogenics . . .

by a plastic membrane. In the event of excessive leakage, localized leak detection methods must be used to locate the leak for repair. It is obviously important that the metal and welding process used for the vessel be such as to assure maximum freedom from porosity; leak detection and repair can be very expensive.

The following trends in the fabrication of cryogenic equipment are predicted for the future:

- New alloys and welding methods will be developed and cheaper materials will supersede some of the popular materials in current use.
- The low-temperature limits for improved carbon and low-alloy steels will be extended downward as more knowledge is gained. Better rules will be developed for low-temperature service.
- New special alloys having extremely low thermal conductivity and high strength will find a ready market when they are developed.
- Data on low-temperature properties of metals will be extended to liquid hydrogen (−423° F.) and helium (−452° F.) temperatures.
- Improvements will be made in test methods for measuring and specifying toughness at low temperatures.
- The construction of vessels for use at low temperatures will continue to increase both in quantity and diversity of application.

Commercial LEADS THE WAY



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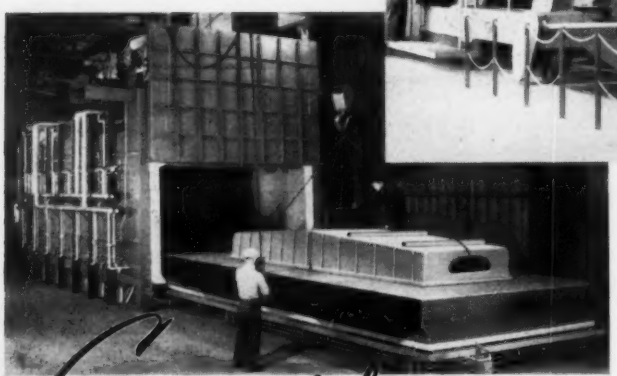

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Circle 1434 on Page 48-B

Precoated Metals . . .

(*Continued from p. 132*)

the base metal. Present fabricating equipment can handle high-gloss to dull-finished prepainted stock with only minor changes in clearance settings.

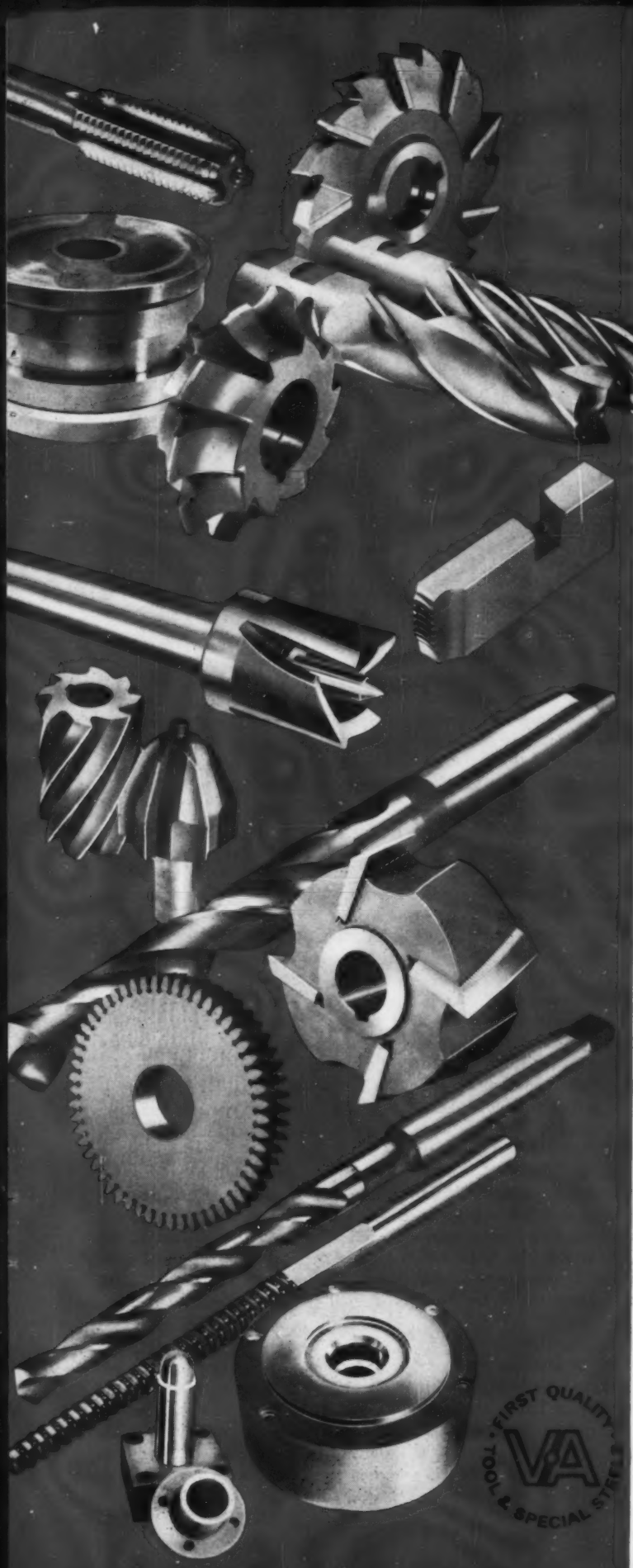
Stainless Is Now Precoated

Stainless steel sheet and strip may also be obtained in a choice of baked organic coatings. Already thoroughly tested for exposure to weather, chemicals, and physical abuse, it combines the strength and corrosion resistance of stainless steel with the added versatility of full color selection. An important advantage of precoated stainless is its exceptionally long life in outdoor exposure. Compared with other painted metals – including galvanized steel and aluminum – test samples have held up at least five times as long (over 39 months) in a Florida seacoast environment.

Interesting effects can be obtained by combining various colors, perforations, and burnishing procedures on smooth or texture-rolled sheet. The material can be drawn, bent, and rolled to an extreme degree without damaging the color coating.

Embossed Plastic Coatings

There is another type of coating – both decorative and functional – that is applied to metal sheet by spraying or roller coating with a liquid vinyl dispersion. Depending on compound and method of application, the warm coating, varying in thickness from 0.008 to 0.021 in., then enters embossing rolls where the texture or pattern is impressed. Previous comments regarding formability and availability of laminated



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Circle 1435 on page 48-B

need a lubricant for BRIGHT finishes?

FLEXIMET S*

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WRITE FOR BULLETIN 26 and details on other FLEXIMET products

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106TH YEAR

Circle 1436 on page 48-B

Precoated Metals . . .

vinyl coatings apply equally well to this new material. The process does not yet offer the wide selection of colors, patterns, and textures that vinyl laminates do. Organosol and plastisol coatings can claim an important advantage over ordinary painted metal stock: More extreme forming and deformation are permitted. In addition to decorative applications, vinyl dispersion coatings have held up well in heavy-duty industrial applications such as linings for tanks and vessels carrying corrosive chemicals.

Steel . . .

(Continued from p. 121)

Good Welding Characteristics

Heat treated constructional alloy steels are, of course, not as easily welded as the other steels listed in the Fact Sheet but their chemical analysis has been carefully chosen to prevent great difficulty if a few simple precautions are taken.

For example, it is important to keep hydrogen out of the weld to prevent underbead cracking. When manual-arc welding is done, low-hydrogen electrodes which match the strength of the base metal should be used; their coatings must be dry. Inert-gas-shielded metal-arc welding and submerged-arc welding can also be employed.

Another important consideration is the cooling rate which is produced during welding. Under normal conditions, cooling is rapid enough to produce the desired microstructure. But preheat is not usually recommended and small weld beads and stringer-bead, multiple-pass deposits should be used. The idea behind these recommendations is to obtain a cooling rate that is fast enough to produce martensite and lower bainite. Only then will the weld and its heat-affected zone match the strength and toughness of the base metal.

Engineers have also counted on the versatility of stainless steels in designs which require high strength and weldability. The result has been that these steels have assumed new and growing importance for structures used at high and low temperatures, in the transportation and chemical industries, and, more recently, in the aircraft and missile industry. In *Metal Progress* next month, the characteristics of stainless steels – from the ferritic grades to the high-strength precipitation hardening and semi-austenitic grades – will be discussed. The article will also point out factors that are important to the proper application of stainless in welded structures.

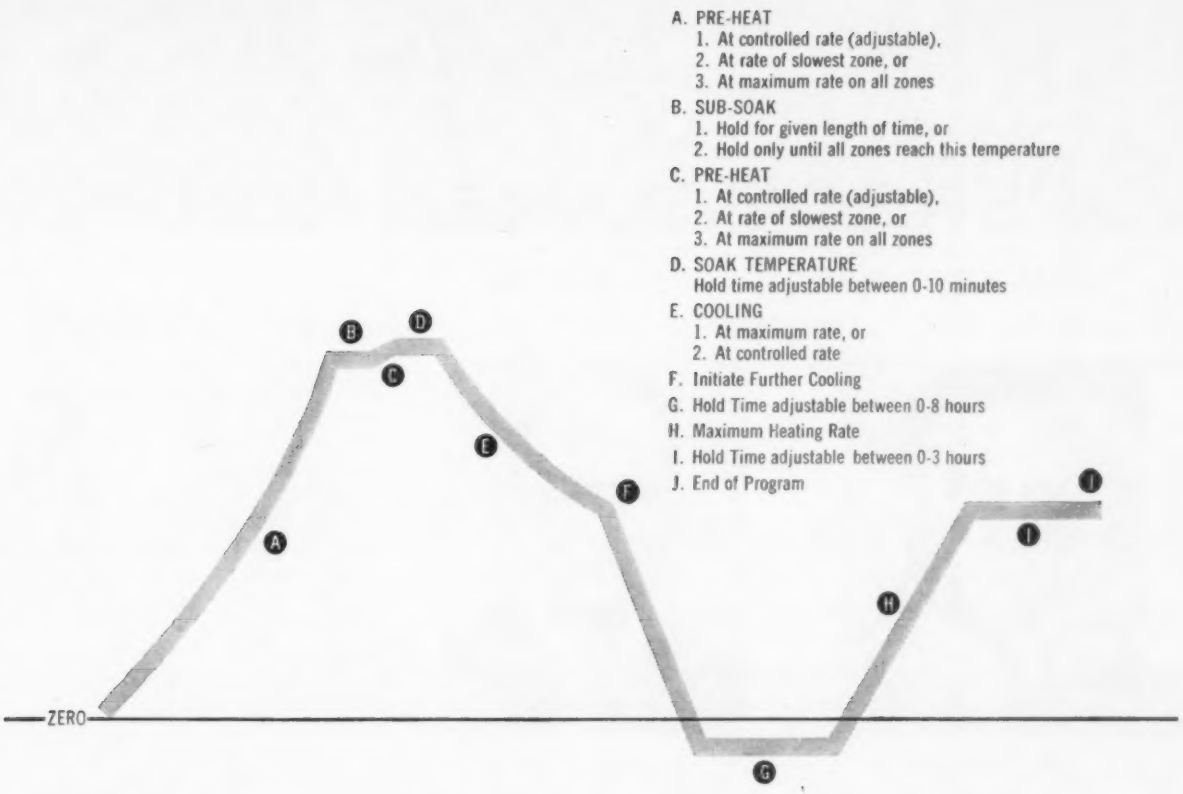
Thermostats . . .

(Continued from p. 134)

and thicknesses. Such projections are normally formed on the thickest component except where the electrical and thermal conductivity of the alloy with the thinner gage greatly exceeds that of the heavier component.

Since strip is usually supplied in a bright, clean condition, it seldom requires further cleaning prior to welding. However, if materials are stored for long periods, they often become contaminated by rust, oxide, oil, grease, paint and dirt, all of which are normally detrimental to welding. Therefore, before welding, all such substances should be removed from the surface by chemical or mechanical cleaning. This improves weldability considerably, and helps maintain consistency of the welds. If possible, the parts should also be welded prior to the stabilizing heat treatment required on thermostat metal parts. When this is done, a reducing atmosphere is not needed. (When heat treatment is specified, either a reducing or oxidizing atmosphere is employed, the former being used when subsequent welding operations are to be made because it leaves the surface in a clean, bright condition.)

The Fact Sheet lists most of the alloys for the manufacture of thermostat metals. All of them can be welded to the materials which are normally considered weldable. Of course, the degree of metallurgical bond depends on many factors, just as it does with single-component materials. Thus, as stated before, this chart was prepared as a qualitative guide to the engineer who uses thermostat metals.


A. PRE-HEAT
1. At controlled rate (adjustable),
2. At rate of slowest zone, or
3. At maximum rate on all zones
B. SUB-SOAK
1. Hold for given length of time, or
2. Hold only until all zones reach this temperature
C. PRE-HEAT
1. At controlled rate (adjustable),
2. At rate of slowest zone, or
3. At maximum rate on all zones
D. SOAK TEMPERATURE
Hold time adjustable between 0-10 minutes
E. COOLING
1. At maximum rate, or
2. At controlled rate
F. Initiate Further Cooling
G. Hold Time adjustable between 0-8 hours
H. Maximum Heating Rate
I. Hold Time adjustable between 0-3 hours
J. End of Program
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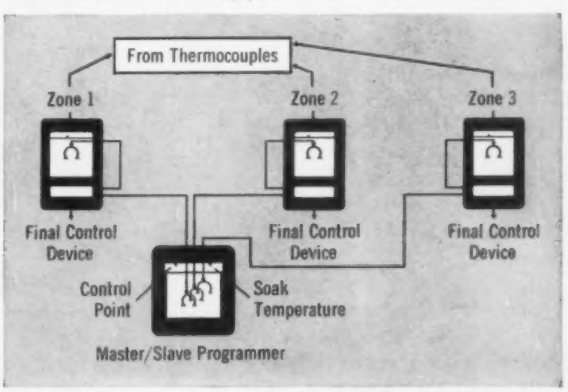

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Circle 1437 on Page 48-B

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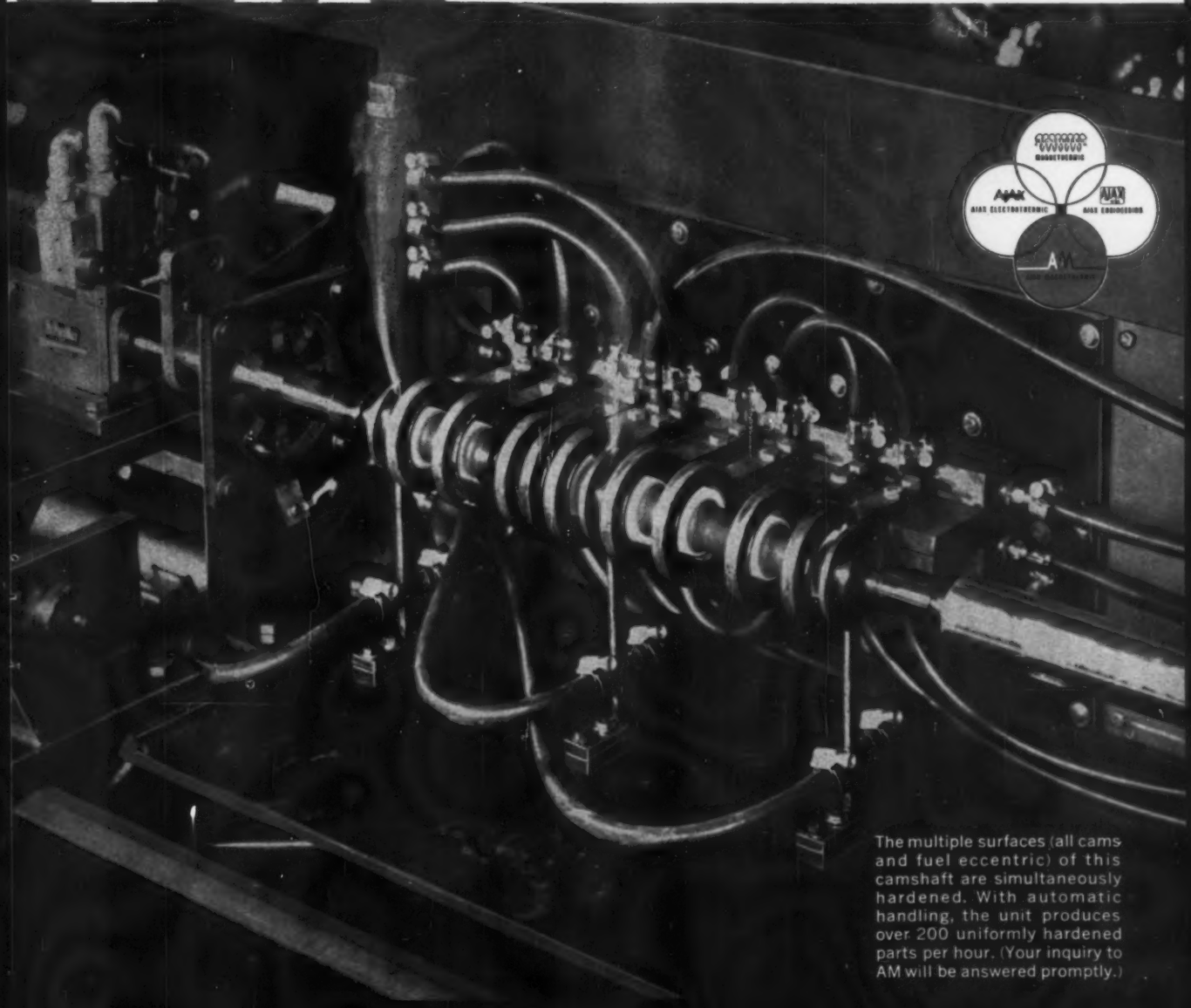
Circle 1438 on page 48-B



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ABSTRACTS of Detroit Convention Papers

. . . a Guide to the Technical Content of Papers Being Presented During Sessions To Be Held at the 43rd National Metal Congress

Mechanical Properties of Steels

Monday, October 23 – 9:00 a.m.

Some Parameters Affecting Fracture Toughness of High-Strength Steel

by Paul M. Lorenz

According to test results, the widths of sheet specimens and the stress levels of the test affected the fracture toughnesses (G_c) of A.M.S. 6427 (A.I.S.I. 4330 modified with vanadium) quenched and tempered to 220,000 psi. tensile strength. With increasing specimen width to 24 in., fracture toughness rose and leveled off at 3200 in-lb. per sq.in. Fracture toughnesses also remained fairly constant for stress levels below the proportional limit, but decreased at a constant rate above this limit to approach zero at levels equal to the ultimate strength of the material. Some specimens were prestressed; however, this treatment appeared to have little effect on the fracture toughness.

Yield Behavior of Certain Alloy Steels at Low Strain Values

by G. S. Reichenbach, D. A. Brown and P. G. Russell

Because some of the newer mechanical devices (precision gyroscopes, for instance) have very stringent accuracy requirements, values representing the conventional mechanical properties (such as "yield point" and "tensile strength") are often not adequate for designing these systems. "Yield strength", for example, is usually defined as the stress needed to produce 0.2% plastic strain. However, the newer designs call for preloading of certain parts to fairly high levels; yet, plastic deformation cannot be tolerated. For this reason, it is necessary to know how a material will behave plastically under strain rates much slower than those conventionally used under standard testing conditions.

For this work, specimens of A.I.S.I. 52100, Type 440C, M50, M2 and M4 were tested in tension and torsion, a capacitance strain gage being used to indicate small levels of residual plastic strains. According to these tests, there may be no real elastic limit if permanent distortion can be measured with enough precision. Stresses required to produce a plastic strain of 1 micro-in. per in. may be only 10 to 15% of the stress needed for the usual 0.2% strain specified by the conventional definition for yield point. Also, if residual stresses due to phase transformations are present, they may have a significant effect on plastic behavior at low stress levels.

Noxious and Innocuous States of Hydrogen in Iron

by D. J. Adenis and W. M. Baldwin, Jr.

According to this investigation, hydrogen can be present in two different states, only one of which embrittles steel. Through various treatments, these states can be shifted back and forth so that the presence of hydrogen can be either safe or dangerous. In this investigation, for instance, Armco iron was cathodically charged with hydrogen to embrittle it, and baked to remove the brittleness. However, hydrogen was still present – austenitizing and quenching re-embrittled the baked specimens of Armco iron.

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Circle 1439 on Page 48.8

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Circle 1440 on Page 48-B

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Circle 1441 on page 49-B

Abstracts . . .

Effect of Temper Brittleness on Dry Friction Wear of a Martensitic Steel

by J. J. Kauzlarich, R. R. Hagglund and J. P. Modrak

Though it has been proposed that certain mechanical properties of a given material will affect the progress of metallic wear, this theory has not previously been supported by direct experimental evidence. For this work, specimens of S.A.E. 1040 were quenched and tempered at various temperatures for impact and wear test. The results indicated that the phenomenon of temper brittleness had an important effect in reducing the rate of wear. Ductile materials, according to the theory described here, wear more than comparable temper embrittled materials.

Repeated Tensile Loading of Iron and Steel

by C. P. Sullivan, B. L. Averbach and Morris Cohen

Fatigue failures can occur under pulsating tension in polycrystalline iron and in quenched and tempered steel, according to the results of this investigation. In both the soft iron and the hard steel, microcracks can be initiated at inclusions or inclusion sites. In the latter material, such cracks were rapidly propagated leading to failure; this occurred because the hardened steel did not have enough plastic flow to blunt the front edge of the crack under test conditions.

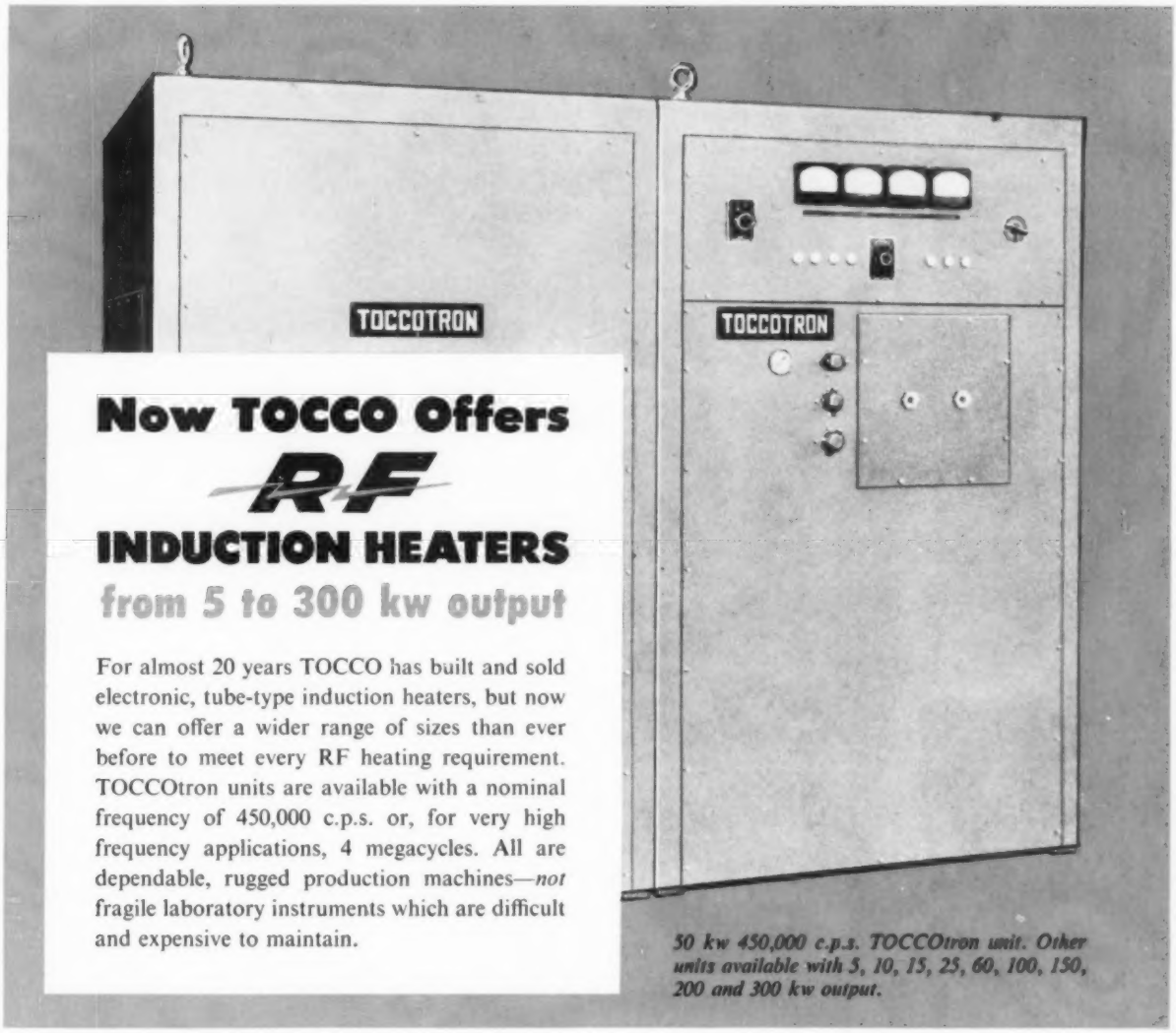
Steels

Monday, October 23 – 2 p.m.

The Effect of Prestraining and Retempering on A.I.S.I. Type 4340

by E. T. Stephenson and Morris Cohen

The prestraining (0 to 3%) and retempering (70 to 1200° F.) of hardened and tempered (400 to 1200° F.) A.I.S.I. 4340 increased its strength and decreased its ductility. As the retempering temperature was raised, these effects were enhanced until the yield-to-tensile strength ratio reached unity, and the stable elongation dropped to zero (though total elongation was still appreciа-



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Circle 1442 on Page 48-B

Post-Forming: New Way to Bigger Savings with Malleable Castings

The ductility of Malleable iron castings permits use of high-speed forming techniques to finish Malleable parts at lower cost. Take advantage of the versatility you get only with ferritic and pearlitic Malleable castings. For a fuller understanding of how Malleable can help you, call any producer that displays this symbol —

Free Folder describing these techniques is available for your use. Just ask any member of the Malleable Castings Council for Data Unit No. 116, or write to Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.

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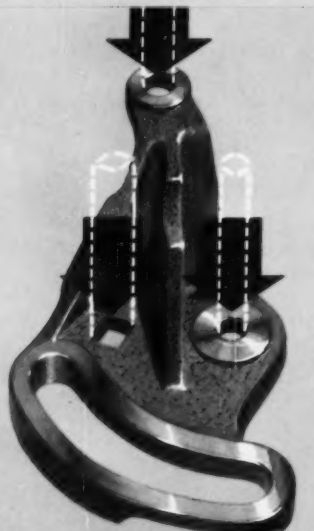
Hot Form It — Hot coining this Malleable transmission part reduces finished cost . . . eliminates three cutting operations required by the previously used steel part.

Roll It — Oil grooves in lawnmower crankshafts and splines in compressor crankshafts are just two of many places where rolling proves more economical than machining.



Punch It — Holes with diameters greater than the thickness of the metal can be punched in Malleable. Two round holes and a square hole are punched simultaneously in this idler arm.

Spin It — Malleable's ductility permits the sleeve and end disc in this ball joint to be held in place by spinning the Malleable housing into a strong, permanent flange.

Get the most for your metals dollar...get MALLEABLE

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Connecticut Mall. Castings Co., New Haven 6
Alloy Foundries Division,
The Eastern Co., Naugatuck

ILLINOIS
Central Fdry. Div., Gen. Motors, Danville
Chicago Malleable Castings Co., Chicago 43
Moline Iron Works, Moline
Moline Malleable Iron Co., St. Charles
National Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Albion Malleable Iron Company,
Muncie Division, Muncie
Link-Belt Company, Indianapolis 6
National Castings Co., Indianapolis 22

IOWA
Iowa Malleable Iron Co., Fairfield

MASSACHUSETTS
Belcher Malleable Iron Co., Easton

MICHIGAN
Albion Malleable Iron Co., Albion
Auto Specialties Mfg. Co., Saint Joseph
Cadillac Malleable Iron Co., Cadillac
Central Fdry. Div., Gen. Motors, Saginaw

MINNESOTA
Northern Malleable Iron Co., St. Paul 6

MISSISSIPPI
Mississippi Malleable Iron Co., Meridian

NEW HAMPSHIRE
Laconia Malleable Iron Co., Laconia

NEW YORK
Acme Steel & Mall. Iron Works, Buffalo 7
Frazer & Jones Company Division
Eastern Malleable Iron Co., Solvay
Oriskany Malleable Iron Co., Inc., Oriskany
Westmoreland Mall. Iron Co., Westmoreland

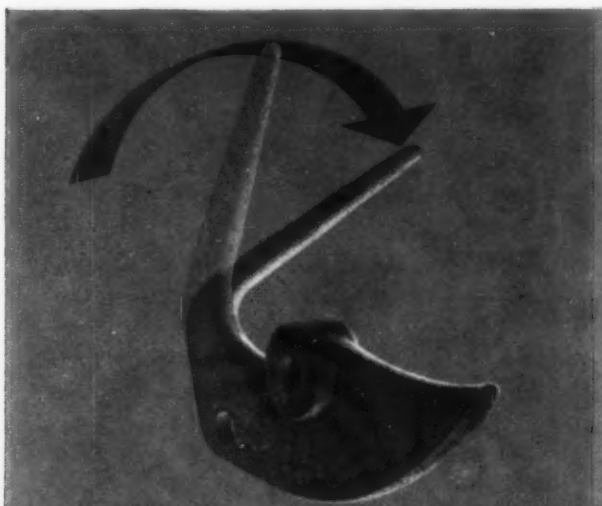
OHIO
American Malleable Castings Co., Marion
Central Fdry. Div., Gen. Motors, Defiance
Dayton Mall. Iron Co., Ironton Div., Ironton
Dayton Mall. Iron Co., Ohio Mall. Div.,
Columbus 16
National Castings Co., Cleveland 6

PENNSYLVANIA
Buck Iron Company, Inc., Philadelphia 22
Erie Malleable Iron Co., Erie
Lancaster Malleable Castings Co., Lancaster
Lehigh Foundries Company, Easton
Meadville Malleable Iron Co., Meadville
Pennsylvania Malleable Iron Corp., Lancaster

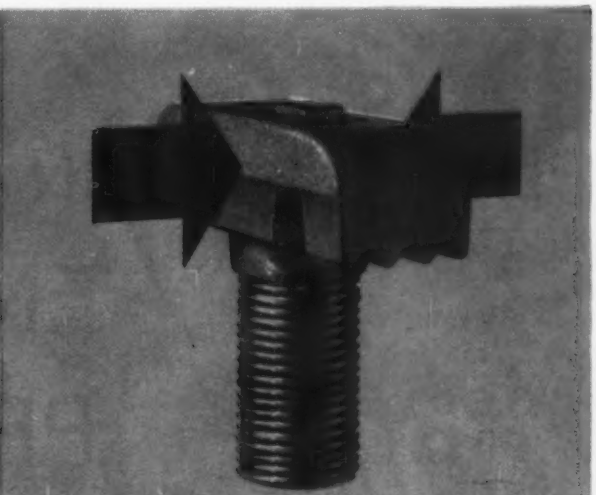
TEXAS
Texas Foundries, Inc., Lufkin

WEST VIRGINIA
West Virginia Mall. Iron Co., Point Pleasant

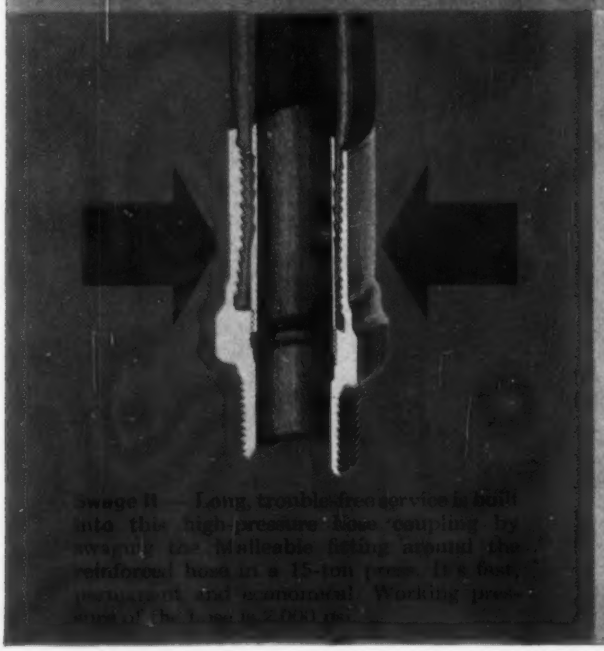
WISCONSIN
Belle City Malleable Iron Co., Racine
Chain Belt Company, Milwaukee 1
Federal Malleable Company, Inc.,
West Allis 14
Kirsh Foundry Inc., Beaver Dam
Lakeside Malleable Castings Co., Racine
Milwaukee Malleable & Grey Iron Works,
Milwaukee 46



Bend it — A 30% cost reduction was achieved by casting this Malleable iron twine finger flat . . . then bending the arm about 45 degrees and coining the center hub in one fast, post-forming operation.



Coin it — Very close tolerances are often met economically by either cold or hot coining. The head of this T-bolt is coined to meet tolerances of ± .005" on its .475" width without any machining.



Swage it — Long, trouble-free service is built into this high-pressure hose coupling by swaging the Malleable fitting around the reinforced hose in a 15-ton press. It's fast, permanent and economical. Working pressure of the 3-way is 2,000 psi.

Harden it — Surface hardness values in excess of 55 Rockwell C can be achieved with pearlitic Malleable by either flame or induction hardening. Response is excellent, and results are uniform.

Circle 1443 on Page 48-B

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FOR BETTER DESIGN...

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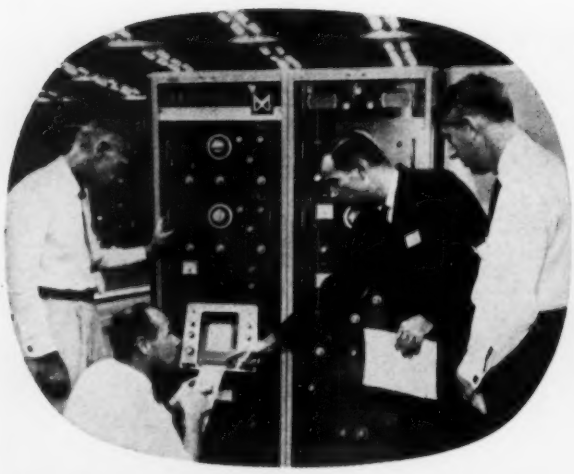
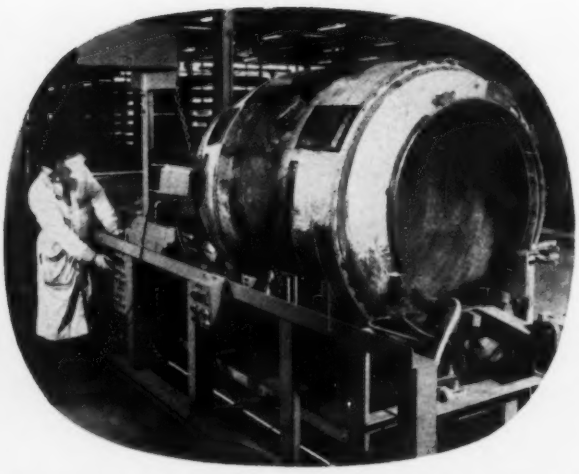


Planned testing of critical tubing ⅛" to 6" O.D. with eddy currents. Magnatest FW-400 is used here for both research and production testing of stainless steel and aluminum tubing. It is one of a broad line of Magnatest units testing nonmagnetic tube, rod and wire—for seams, inclusions, voids, concentrated porosity, embrittled areas, slivers, laps, etc. Defects are reported on the scope and/or other readout, at mill speeds if necessary.

Photo courtesy GENERAL DYNAMICS/FORT WORTH



Planned testing of rocket motor solid fuel chambers. This specially researched and developed Magnaglo unit provides multi-directional magnetization for positive detection of all crack-type defects. In designing specialized-purpose units like this for inspection of highly critical components and parts, Magnaflux draws upon an impressive background of hundreds of thousands of man hours spent in its own R & D, and experience in planned engineering of test equipment for virtually every industrial need.

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Such benefits in reliability—and production savings, too—can be realized every day, with Magnaflux Test Systems planned for and used at every stage from first concept to full production testing. Whether for large volume, or few-of-a-kind critical parts, or prototypes, Magnaflux offers you the widest variety of different test systems and methods.

A few typical examples are shown here. Many others could be. For your own requirements—however commonplace, critical or specialized—there is usually a Magnaflux Test System. Call your Magnaflux Field Engineer—or write Magnaflux Corporation, 7322 W. Lawrence Avenue, Chicago 31, Illinois.

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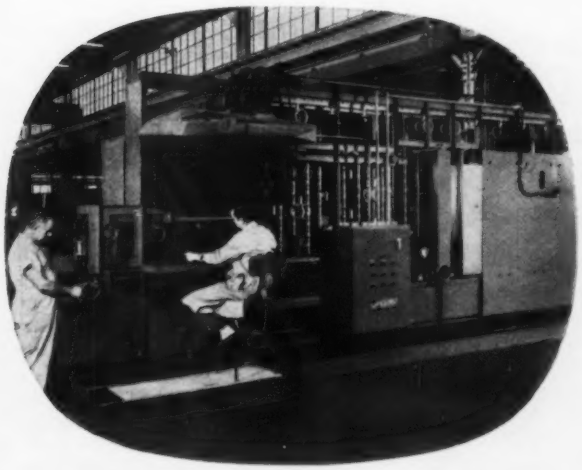
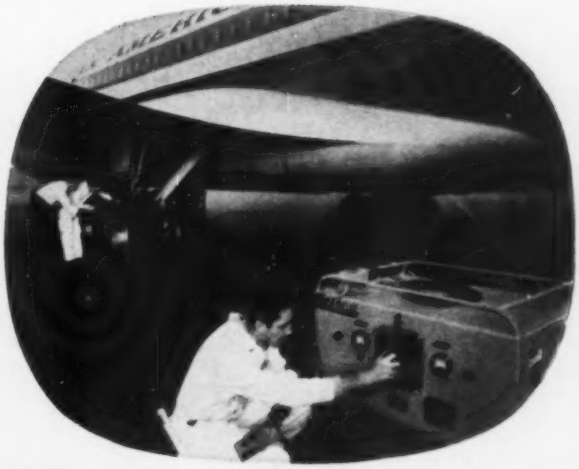


Planned testing of bearing cages. This is a specialized, automated Zyglo Fluorescent Penetrant System with which one man tests up to 375 nonferrous bearing cages per hour for cracks, porosity or leaks. It includes complete conveyorized handling and programmed processing, custom engineered and built by Magnaflux. Parts tested range from ¾" I.D. to 10" O.D. Twenty-six different Zyglo Penetrants have been developed by Magnaflux to produce precise, 100% reproducible results, assure sensitivity to meet all needs.



Planned apron check of a jet liner's main gear is made with Magnaflux KCH-3D and black light. Such tests are routine to assure safety on major airlines serving throughout the world. Magnaflux units like this are versatile, and are also used in all sorts of industrial maintenance operations as well as in production testing of large castings, structural weldments, etc. Photo is of Pan American Boeing 707 at Idlewild Airport, New York.

Circle 1444 on Page 43-E

PROBLEM...

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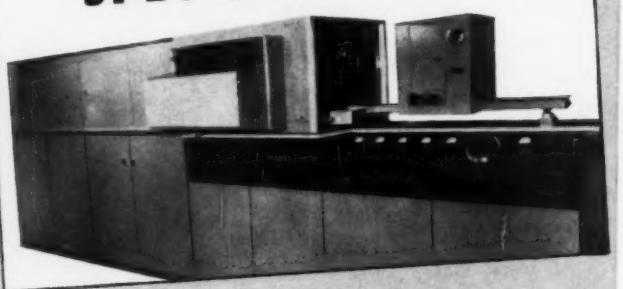
TO DO ROUTINE ANALYSES

AND THE "ODD SAMPLE."

SOLUTION...

CONVERTIBLE EBERT SPECTROGRAPH



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Circle 1445 on page 48-B

Abstracts . . .

ble). Electron micrographs indicated that carbides in the tempered martensite were dissolved and reprecipitated by straining and retempering; this accounted for some of the observed changes.

As to practical implications, these results appear to indicate the strengthening of A.I.S.I. 4340 imparted by prestraining is of limited usefulness, and may be dangerous under some circumstances. Without stable elongation, for example, the steel could stretch plastically to fracture under *decreasing* loads after the yield point is reached.

Direct Reduction of Ferric Oxide by Solid Carbon in Vacuum

by T. S. Yun

Ferric oxide was reduced to metallic iron by solid carbon (in the form of fine graphite) at temperatures ranging between 700 and 1100° C. (1300 and 2000° F.). To secure a true direct reduction, the process was carried out in a high vacuum so that CO and CO_2 would be removed immediately after forming. According to the results, metallic iron can be produced from ferric oxide only above 900° C. (1650° F.). The investigation also established that the diffusion of iron ions within the oxide crystal was the rate-determining process in the reduction of ferric oxide.

The Effect of Concurrent Straining on the Annealing Behavior of a Cold-Rolled Vacuum-Melted Electrolytic Iron

by Alfred Goldberg and Sumner Gurney

In static annealing (annealing without straining), cold-rolled iron softens at high temperatures largely because of recrystallization. However, at lower temperatures, increased polygonization interferes with recrystallization to slow the softening process. When the same iron is strained while being annealed, a hardness drop occurs which appears to be independent of the strain rate or temperature. However, a fast strain rate at a temperature where recrystallization plays a major role in static annealing retards softening. Apparently, the concurrent straining interrupts recrystallization by inducing or accelerating (or both) polygonization.

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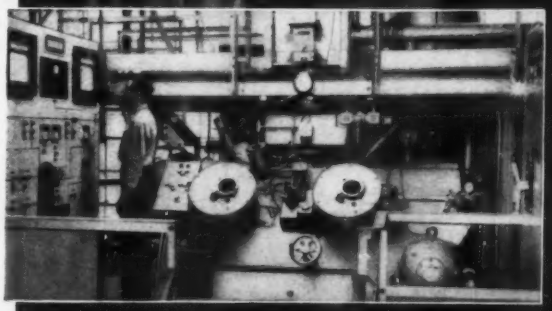
VISIT BOOTH 314 at the Metal Show



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Circle 1447 on page 48-B

Abstracts . . .

Effects of Columbium on the Properties of Aluminum-Killed, Medium-Carbon Steel

by E. E. Fletcher, A. R. Elsea and E. C. Bain

In A.I.S.I. 1035, columbium provided a strong resistance to grain growth at elevated temperatures, steels containing 0.35% Cb having a fine grain size after being austenitized at 2000°F. Columbium carbides went into solution very slowly; undissolved carbides remained in some steels even after they were austenitized at 2300°F. Columbium (0.012%) also raised the yield point of the steel (by 3400 psi., as-normalized; higher values for various quenched and tempered conditions) without affecting the ductility as measured by elongation or reduction in area. In most instances, columbium also lowered or did not affect the transition temperature.

Some Processing Factors Affecting Magnetic Properties of Low-Carbon Steel

by D. J. Knight and P. J. Adzema

Magnetic properties of low-carbon steel are dependent primarily upon grain size, and the amount and form of carbon present. In this study, which was made to relate processing variables with these metallurgical factors, the authors found that carbon content had a strong influence in controlling magnetic properties. When the steel's carbon content was about 0.06%, its magnetic properties did not approach those of steels with less than 0.01% C even if its grain size was much larger. Furthermore, a low carbon content obviated the deleterious effect of rapid cooling from the annealing temperature.

Carbides in Steels

Tuesday, October 24 – 9:00 a.m.

A Study of Carbide Composition and Microstructure During Quenching and Tempering of a 5% Cr-Mo-V Steel

by G. P. Contractor, E. G. Schempp and W. A. Morgan

In this steel (0.34 C, 5.08 Cr, 1.43 Mo, 0.92 V), studies of ex-

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Photomicrograph of properly hardened carbon steel. Note the small amount of retained Austenite (white). Texaco quenching oils consistently give outstanding results like this.

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Circle 1448 on page 48-B

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Also manufacturers of PYRO-EYE® Two-color Optical Pyrometer

Circle 1449 on page 48-S

Abstracts . . .

tracted residues of carbides indicated that the amount of undissolved carbides decreased in the steel as the austenitizing temperature increased. From 2100 to 2600° F., however, there was little apparent change in weight percent of undissolved carbides. As for the effect of tempering temperature, a minimum amount of carbides (2.25%) remained after tempering at 900 to 975° F.; this temperature corresponded with a peak in the hardness - tempering temperature curve. Electron microscopy and x-ray diffraction studies of extracted carbides showed that secondary hardening in this steel was due to re-solution of $(Fe,Cr)_3C$ and the formation of a coherent alloy precipitate.

Creep Behavior of an Austenitic Stainless Steel as Affected by Carbides Precipitated on Dislocations

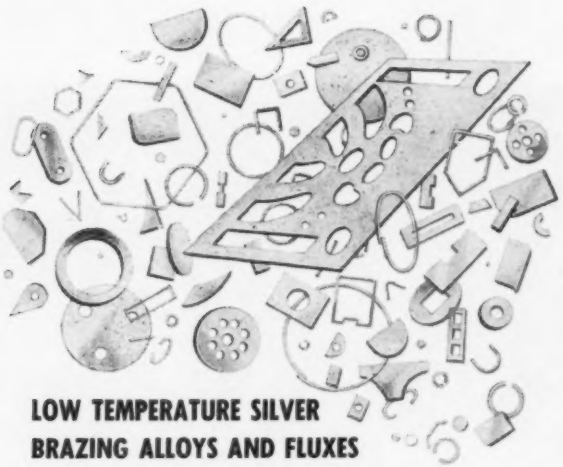
by Frank Garofalo, F. von Gemmingen and W. F. Domis

When Type 316 stainless steel was prestrained at room temperature and heated between 900 and 1300° F., $M_{23}C_6$ particles precipitated at dislocation sites, the number of particles per unit area increasing as prestrain was increased to 25%. (Above a 25% prestrain, the carbide particles agglomerated to a degree in tempering.) This treatment enhanced creep properties at 1100, 1300 and 1500° F., the minimum creep rate at 1300° F. being decreased by as much as 250 times. At 1100° F., rupture life could be increased by as much as 25 times.

Microstructural and Residual Stress Changes in Hardened Steel Due to Rolling Contact

by J. J. Bush, W. L. Grube and G. H. Robinson

For this work, the authors examined the relationship of running time and contact load to the extent and appearance of microstructural alterations in roller bearings made of hardened A.I.S.I. 52100 steel. They found that the "stress-affected zone" of altered microstructure consisted essentially of extruded carbides and highly deformed ferrite bands. However, this change occurred only after a threshold load



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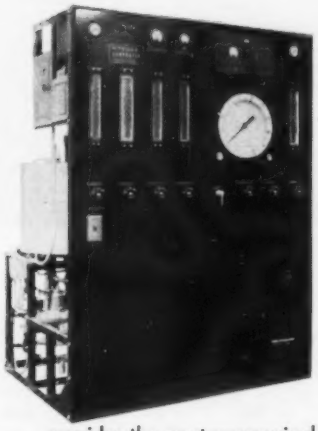

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Circle 1450 on page 48-B

GLX-W COLUMBIUM-TREATED CARBON STEEL CUTS DEAD WEIGHT 10% IN NEW

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That's the Beauty of Steel

Bringing important new economies to rail shipment of automobiles, this new tri-level auto carrier holds twelve standard cars or mixed loads of 14 standards and compacts. Capacity is increased up to 75%. A unique system of hydraulically positioning the vehicles on three levels gives a clearance of only 16 feet 8 inches, permits use in areas formerly limited to bi-level unit operation because of clearance requirements. ◆ Key feature of the Multi-Car Carrier is the movable decks on which the cars ride. Made of GLX-W columbium-treated steel, the decks are raised and lowered by built-in hydraulic lifts, actuated by a portable power unit. Here light weight was essential, in order to reduce the operating power requirements. Yet great strength was necessary, too, to support the payload. Finally, design of the decks called for eight bends in each section. So formability was also a must. ◆ GLX-W met and exceeded all these requirements. It gives 50-100% greater strength than mild carbon steel, so builder Whitehead and Kales could get the required strength with less weight. Deck operating units need less power,

Great Lakes Steel is a Division of

Multi-Car Carrier built by Whitehead and Kales for Multi-Car Corporation, Detroit, Michigan

TRI-LEVEL AUTO CARRIER

and total weight is reduced approximately 5,000 pounds or 10%. Production is more economical, too, because the ductility and formability of GLX-W permits four of the bends in the deck to be performed in one press operation. ◆ The GLX-W series of high-strength steels consists of fine-grained, semi-killed mild carbon steels, treated with varying amounts of columbium. The high strength of GLX-W permits designers to reduce the amount of steel and effect considerable cost savings when replacing mild carbon steel. GLX-W steels have a low carbon content and are readily weldable and formable. GLX-W steels are available at four minimum yield strength levels: 45,000, 50,000, 55,000 and 60,000 p.s.i. and in sheets, plates and bars. For complete technical information, write Great Lakes Steel Corporation, Product Development, Dept. MP-9, P. O. Box 7310, Detroit 2, Michigan.

GLX W PATENT PENDING

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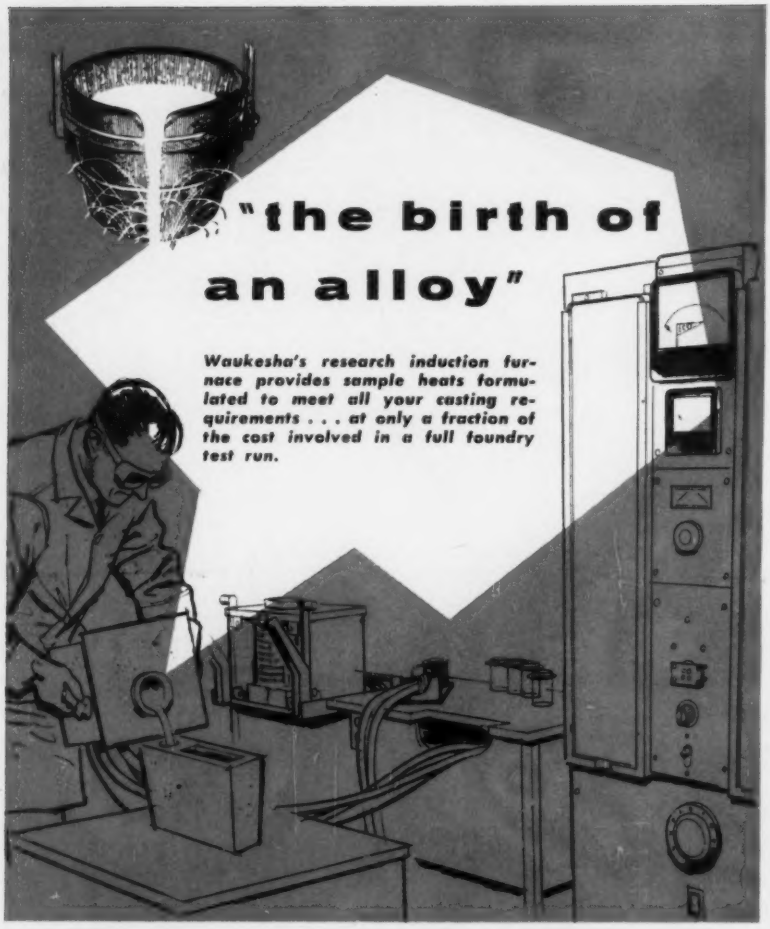
Circle 1451 on page 48-8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Circle 1452 on page 48-B

Abstracts . . .

stress was reached and passed. In conclusion, though extensive microstructural alterations appear to take place under high stresses, the authors postulate that spalling may be prevented – the extrusion of carbides seems to inhibit the development of fatigue cracks in the region of maximum plastic deformation.

An Electron Transmission Study of the Tempering of Martensite in 0.42% C Steel

by A. M. Turkalo

According to microscopic examination by electron transmission techniques, as-quenched martensite appears as needles often with striae (interpreted to indicate twinning) and with no precipitated carbides. On tempering at 400° F., carbides precipitate to form fine films at needle boundaries and acicular carbides within the needles. With higher tempering temperatures, these carbides coalesce and spheroidize. Temperature dislocations appear at about 800° F., and at 1100 and 1250° F., dislocation networks associated with grain boundaries are clearly defined, carbides being visible within the grains.

Iron-Chromium Alloys

Tuesday, October 24 – 2:00 p.m.

Influence of Delta Ferrite-Carbide Segregates on Properties of 12% Cr Steel

by E. A. Loria

In this steel, a Type 422 stainless grade, the detrimental effects of delta ferrite-carbide segregates on ductility were determined by various laboratory tests of mechanical properties. If the composition was properly balanced, ingots up to 26 in. in diameter could be produced free of ferrite. However, according to this investigation, up to 5% ferrite can be tolerated if it is not severely striated by subsequent rolling or other working process. If massive discontinuities (carbides or ferrite-carbide segregates) are present, they will lower the tensile properties regardless of testing direction.

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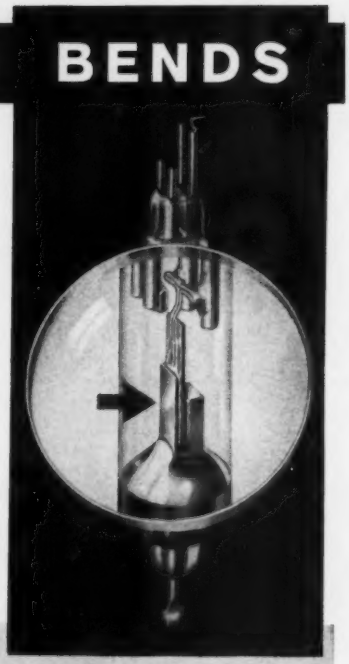

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Circle 1453 on page 48-S

Submicroscopic Structures in Tempering Type 410 Stainless Steel

by J. J. Hauser, J. M. Capenos and B. R. Banerjee

Examination of this steel by electron microscopy, electron - probe analysis, and other methods clarified the detailed kinetics of tempering reactions, and revealed many interesting structural changes. As quenched, the steel contained dislocation networks in a martensitic structure and filmy precipitates of carbides. When the steel was tempered, M_3C carbides precipitated to grow as the temperature rose. However, at 900° F., most of the M_3C carbides had redissolved (being somewhat unstable), and M_7C_3 and $M_{23}C_6$ carbides had nucleated independently at boundaries and matrix imperfections. Chromium-depleted regions were observed in specimens tempered at 1000° F.; this reaction probably contributed to the decreased corrosion resistance of Type 410 tempered in the 800 to 1000° F. range. At 1100° F. and above, alloy nitrides of the M_2X type appeared. Other observations: vacancy dislocation loops, martensitic embryos, dislocation phenomena such as wavy dislocations, dislocation pile-ups, and subboundaries.

Relationship Between Fatigue and Damping Characteristics and Microstructure of 12% Cr Steels

by E. J. Dulis, V. K. Chandhok and J. P. Hirth

According to this work, 12% Cr steels (such as Type 410) which contain substantial amount of delta ferrite (15 to 20%) have unusually high fatigue strengths and damping capacities at 500 to 700° F. The enhanced strength was related to the precipitation of alpha prime (a high-chromium, body - centered cubic phase) in the delta ferrite during fatigue testing.

Nuclear Metals

Wednesday, October 25 – 2:00 p.m.

Liquid-Metal Fuel Constitutions III; Liquidus Curves of the Bismuth Fission-Product Systems

by D. G. Schweitzer and J. R. Weeks

The solubilities of the long-lived fission products in liquid bismuth

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Circle 1454 on page 48-B

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Circle 1455 on page 48-B

Abstracts . . .

have been measured at temperatures between 300 and 700° C. (575 and 1300° F.). These include strontium, barium, yttrium, cerium, praeseodymium, neodymium, samarium, germanium, zirconium, molybdenum, tellurium, ruthenium, rhodium and palladium. This work was intended to determine solubilities of individual fission products, the manner in which a selected mixture of them affected the uranium solubility, and the manner in which the noble fission products in large quantities affected the inhibitor solubilities.

Liquid-Metal Fuel Constitutions IV; Effects of Alkali Metals on the Solubility of Uranium in Bismuth

by D. G. Schweitzer and J. R. Weeks

In investigating the effects of alkali metal impurities on the U-Bi liquidus, the authors found that small additions of sodium, potassium and cesium increased the solubility of uranium, but that large additions of sodium decreased it. In theory, since all of the alkali metals (and uranium as well) form intermetallic compounds with bismuth, they can be considered as electron donors to liquid bismuth; this interaction probably contributes to the solubility phenomena. However, according to experimental results, the solubility increase was not directly proportional to either the relative electronegativities or relative atomic diameters of the alkali metals. As a consequence, to date there is no theoretical explanation for the observed solubility effects in these systems.

Metallographic Studies of Al-Ni-U Bonds in Nuclear Fuel Elements

by C. L. Angerman

Through metallographic and x-ray diffraction techniques, the author identified the diffusion zones that occur in as-bonded fuel elements by correlating their appearances with those of similar zones developed in diffusion couples. Four zones were identified: Al_3Ni, Al_3Ni_2, U_6Ni, and UNi_5.

The limiting factor in the quality of the bonds was the presence of an unidentified oxide within the uranium-nickel portion. When this oxide occurred as a continuous layer, bond strength averaged less than

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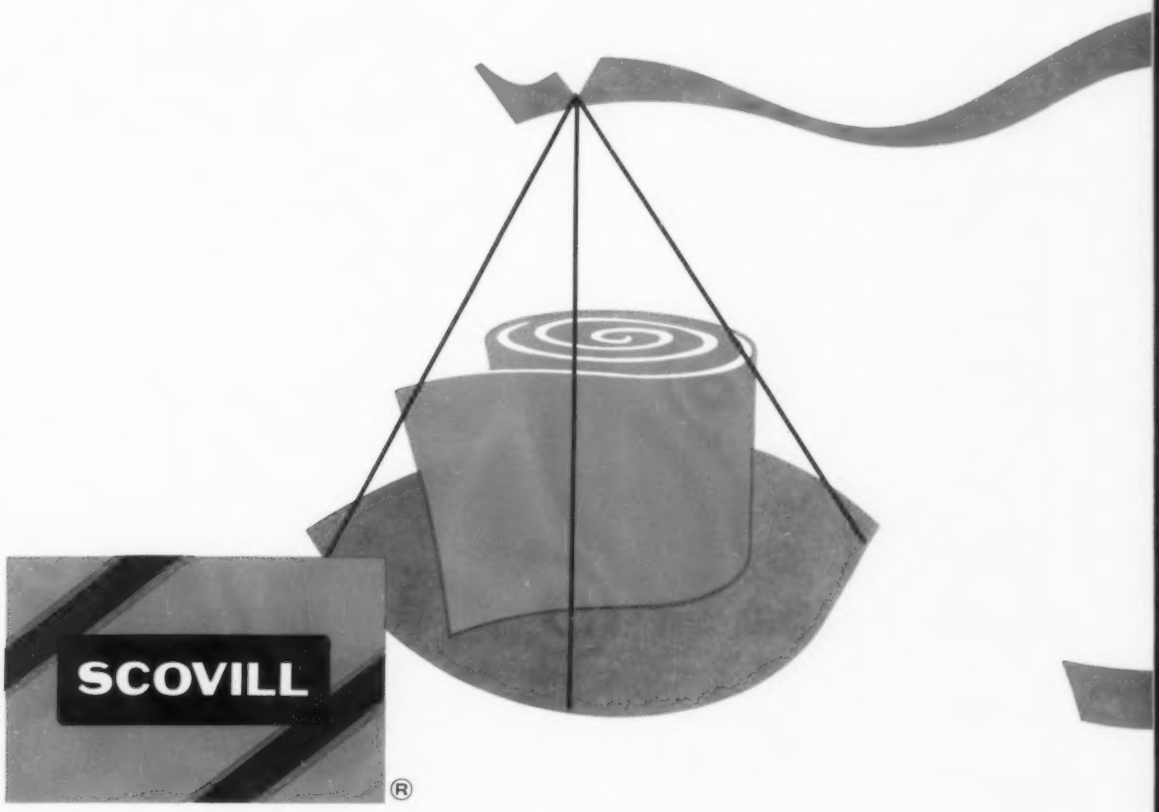

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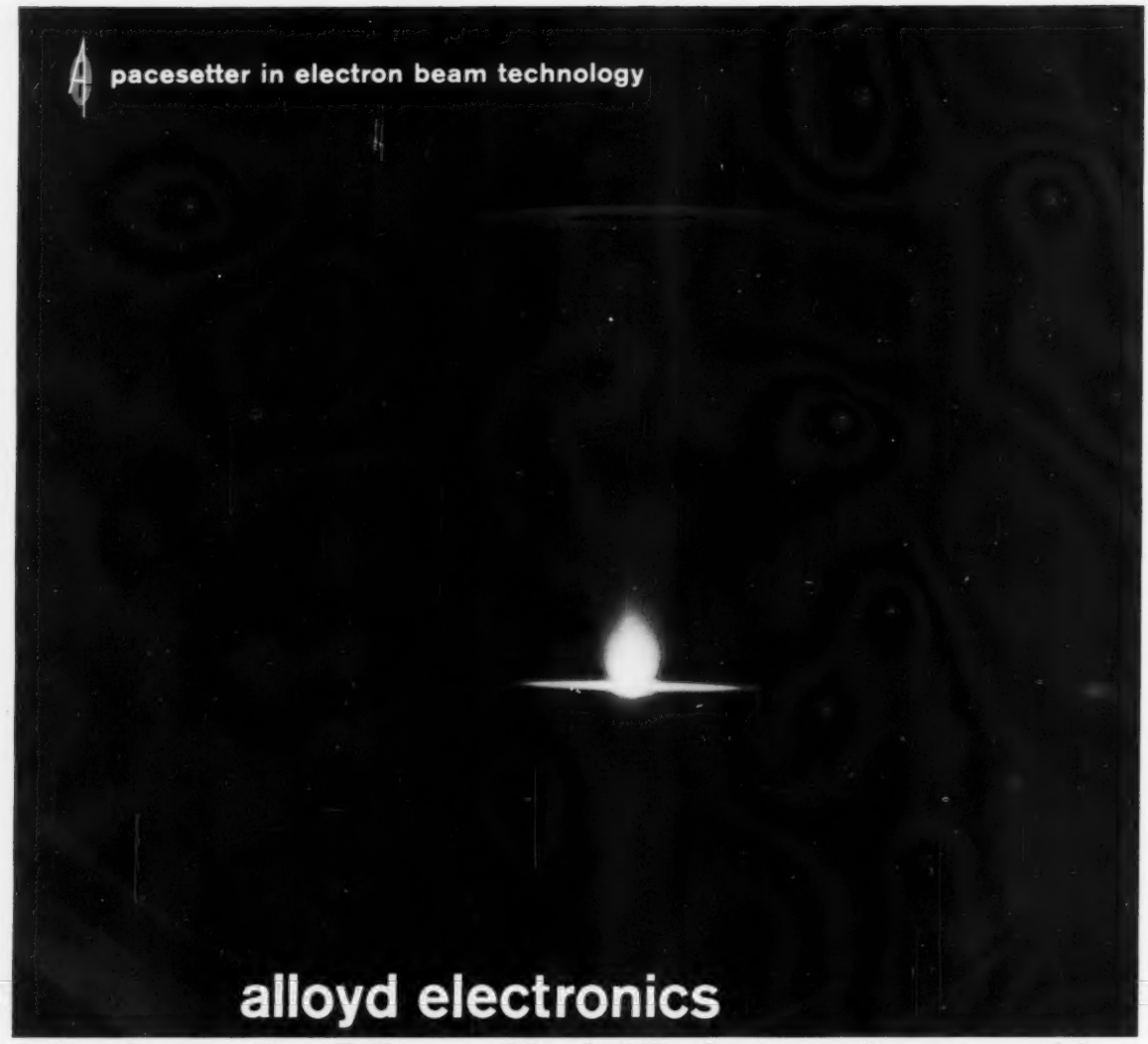

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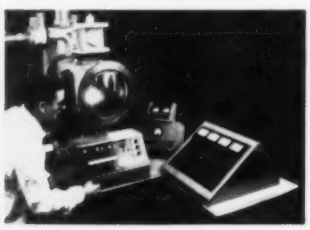

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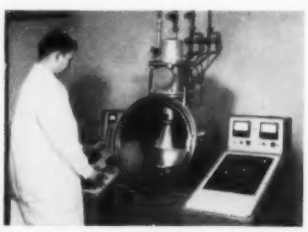

Circle 1456 on page 48-B

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Tool Steel Topics

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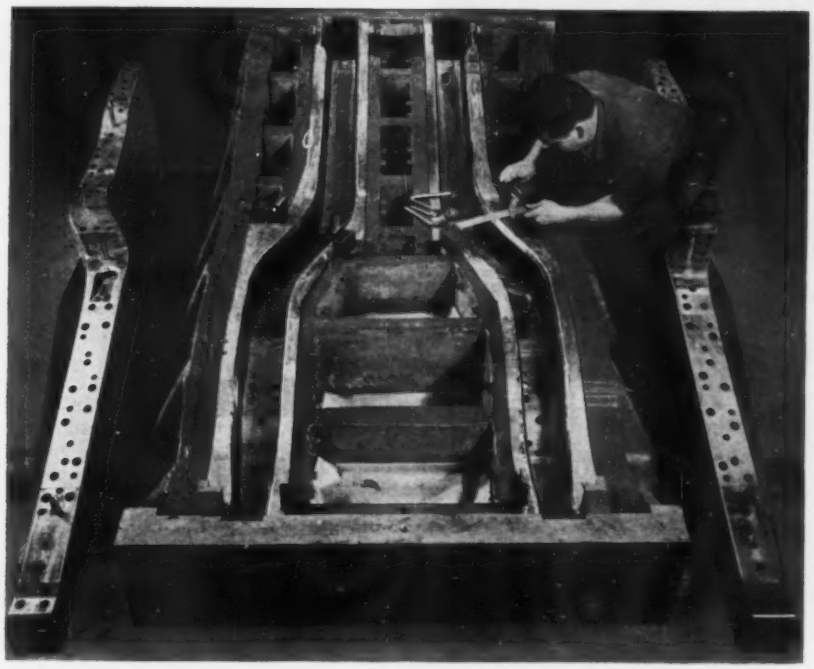

Die of AH-5 Tool Steel
Forms Sheet Steel Auto Frames

This huge die, of Bethlehem AH-5 tool steel, was made by Parish Pressed Steel Division of Dana Corporation to form automobile frames. Hardened to Rockwell C 60-62, the die handles sheet steel .120 in. thick.

Engineers at Parish like the wear-resistance of AH-5, which enables them to produce about 25,000 frames before slight redressing of the die becomes necessary. AH-5's low distortion and good shock-resistance were also singled out for favorable comment.

AH-5 is an air-hardening grade containing 5 pct chromium. It's an easy steel to machine because it can be annealed to 212 Brinell. Here's its typical analysis:

Carbon 1.00 Chromium 5.25
Manganese 0.60 Molybdenum 1.10
Vanadium 0.25

AH-5 assures economical, long-run performance from forming and blanking tools, dies, and punches. For full particulars about AH-5 or any of our other air-hardening tool steels, get in touch with your Bethlehem distributor.

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It's also easy to machine. An air-hardening grade, Lehigh H has a high-carbon, high-chrome analysis.

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Operators of punching, blanking, and shearing equipment recognize that proper clearance between punch and die is necessary for good operation. The right amount of clearance produces the lowest cutting pressure and the least wear on the tools, and also makes possible clean, sheared edges which are free from burrs.

The most common rule for clearance is this: clearance should be about one-tenth the stock thickness. Yet in many shops there's a continual search for some "magic" formula that will more accurately determine the proper clearance . . . which in turn will automatically eliminate whatever type of trouble is current.

There is no need to wait for such a formula to be developed because it is not actually needed. Examination and evaluation of the blanks, or sheared edges being produced, will tell whether the proper clearance is being used. Sheared edges produced with proper clearance will show "shear" (the smooth, shiny portion) for about 1/5 to 1/3 the stock thickness; the remainder of the edge will show "fracture" (this is the rough, granular part). If the "shear" occupies too great a portion of the thickness, it indicates the clearance is too great; when the "shear" is too little, insufficient clearance is indicated. If heavy burrs are present on the sheared edges, and if the blanks are "cupped," then the clearance is too great. Burrs on portions of the sheared edges may indicate misalignment or dull tool edges which, in effect, change the clearance from the amount theoretically present.

Developing and maintaining proper clearance pays off in the production of high quality parts, and also results in minimum tool wear and low tool costs.

Circle 1499 on Page 48-B

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SCIENCE

Circle 1501 on Page 48-B

10,000 psi. Furthermore, the bond corroded rapidly in pinhole tests. However, when the oxide occurred as dispersed particles, bond strength was greater (averaging over 15,000 psi.) and corrosion resistance was much better.

Effect of Oxygen on the Properties of Zircaloy-2

by L. S. Rubenstein, F. L. Shubert and J. G. Goodwin

When oxygen (900 to 10,000 ppm. for this work) was added to Zircaloy-2, it formed a homogeneous alloy with properties that varied according to the amount of oxygen. With increasing oxygen, hot forging and rolling temperatures rose, and cold rolling ductility dropped. As for mechanical properties, yield and tensile strengths rose as did hardness. Finally, corrosion resistance dropped with increasing oxygen content. When over 2000 ppm. oxygen was present, weight gains in corrosion tests were in excess of those currently specified (28 ± 10 mg. per sq.dm.).

Plastic Deformation

Wednesday, October 25 – 2:00 p.m.

Shear Deformation of Magnesium and Zinc Single Crystals

by W. L. Phillips, Jr.

In direct shear, the stress-strain curves of magnesium and zinc single crystals were independent of initial orientation and were recoverable even after strains. With magnesium, extra stress was needed to continue straining the crystal when the slip direction was shifted either 60 or 120°. When the direction of shear was reversed, plastic flow began at a stress much lower than that required for the onset of slip in the original direction. Furthermore, a permanent loss in strain hardening accompanied continued strain. Both the lowering of the flow stress and the permanent loss in strain were proportional to prior strain.

Effect of Stress Decreases on Creep of Aluminum in the Dislocation Climb Region

by L. Raymond, W. D. Ludemann, N. Jaffee and J. E. Dorn

In the dislocation climb region, the instantaneous creep rate depended upon the stress, temperature,

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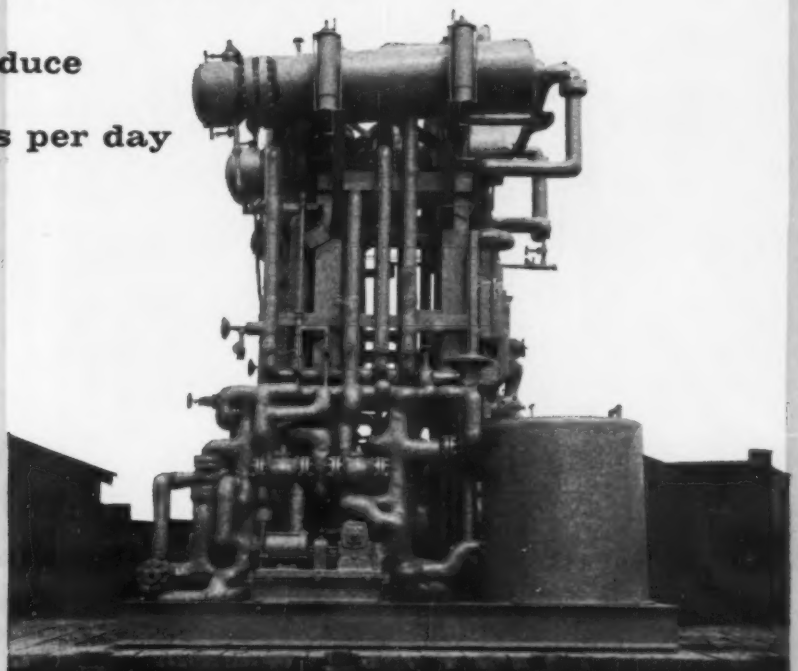

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Circle 1503 on Page 48-B

Abstracts . . .

and the instantaneous substructure. During the primary stage of creep, the decrease in rate was attributed to more closely spaced barriers. As creep continued, the rate decreased until a minimum value was reached; this was presumably due to a thinning out of the piled-up dislocation arrays against barriers. Finally, the creep rate increased to the secondary rate for the new stress. According to the paper, this was the result of recovery of the more closely spaced barriers and their replacement by a new, more widely spaced steady-state distribution appropriate to the new stress. Due to recovery of barriers, the same secondary creep rate was eventually obtained for a given final stress regardless of the preceding creep history.

Investigation of the Intermediate Temperature Ductility Minimum in Metals

by F. N. Rhines and P. J. Wray

According to the authors, the brittleness range which occurs just below the recrystallization temperature in most ductile metals is caused by grain-boundary shearing and associated intergranular rupture. Cavities appear to nucleate at four-grain intersections, and grow intergranularly as long as they lie upon shearing grain boundaries. At normal testing rates, cavity growth is limited to the temperature zone between the recovery and recrystallization temperatures. However, at very low testing rates, a second ductility minimum occurs at somewhat higher temperatures; a critical relationship between recrystallization rates and grain-boundary migration again fosters cavity growth.

Cumulative Fatigue at High Plastic Strains

by Dogan E. Gücer

In engineering, there is a trend towards lowering safety factors and designing structures to last only for the intended life. Thus, it is necessary to know the endurance limit in structures subject to fluctuating loads. In this work, cumulative aspects of high strain fatigue were emphasized; the author showed that cumulative fatigue assumptions were applicable at high plastic strains (from 100 to 2500% above the endurance limit) when stabilized strain range was used as a severity of loading index.

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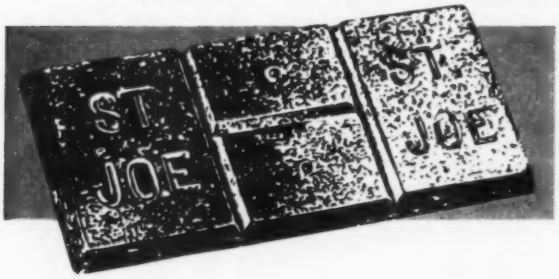

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Circle 1505 on Page 48-B

Centrifugal Creep Testing of Pure Aluminum

by D. E. Deutsch, R. S. Carey and J. L. Hull

Since 1948, Russian engineers have used centrifugal creep testing machines to screen materials for high-temperature applications. This investigation, which was carried out by testing aluminum specimens at temperatures ranging from 323 to 542° K. (120 to 520° F.), showed that this type of test can be used for obtaining quantitative data. Results are in good agreement with those obtained by conventional creep testing. As for advantages of this method of testing, up to 32 tests can be made by centrifugal creep equipment in the time normally needed for one test in a conventional creep testing machine.

Transient and Destructive Instability in Torsion

by N. H. Polakowski and S. Mostovoy

The authors show that cold stretched or drawn polycrystalline copper, iron and some of their alloys deform in torsion by propagation of localized, annular shear zones, and offer a tentative explanation for the phenomenon. The results presented in the paper appear to throw a new light on certain little-understood aspects of the mechanical behavior of metals.

Physical Metallurgy

Thursday, October 26 – 9:00 a.m.

Prediction of Atomic Mobility in Metallic Systems

by O. D. Sherby and M. T. Simnad

According to this report, intended to introduce a method for correlating all self-diffusion data which permits an approximate prediction of atomic mobility, the rate of volume self-diffusion in metallic systems can be predicted by mathematical means.

A New Method for Determination of Liquid–Liquid Equilibria as Applied to the Fe-C-Si-Mg System

by P. K. Trojan and R. A. Flinn

By applying argon at a pressure greater than the vapor pressure of magnesium, a layer of liquid magnesium can be maintained over an iron-base melt without boiling. Through this technique, the experimenters were able to determine the solubility of magnesium in an iron-base liquid; they found it to be up to 3%, much higher than previously supposed. The factors affecting solubility in order of decreasing importance are carbon content, temperature, and silicon content. As a matter of interest, this method can be applied to other alloy systems.

Measurement of Interlamellar Spacing of Pearlite

by B. Gregory, H. T. Hall and G. Bullock

In examining the influence of the numerical aperature of the microscope objective on the spacing of pearlite plates, the authors found that "two-surface" and "partial-resolution" methods gave comparable results when the latter method was performed with an objective with a resolving power greater than the mean spacing of the plates of pearlite. Pearlite spacings in a eutectoid carbon steel have been measured and correlated with isothermal formation temperatures.

Quantitative Metallographic Analysis of Graphite Size in Ductile Cast Iron

by J. H. Brophy and M. J. Sinnott

According to the results of this investigation, the maximum size of graphite spheres present in a casting of ductile iron varies with the thickness of the casting section, the largest spheres being observed in the thickest sections. Within a given section thickness, sphere sizes vary continuously from large to small. However, the average sphere size throughout the casting is essentially independent of the casting section thickness. The authors suggest that the sphere size apparent to the observer of a micrograph is the maximum size for the particular section; therefore, the average size of sphere in the casting is unrecognized because it is relatively constant throughout all sections.

Wrought Lead-Cadmium-Nickel Alloys

by D. N. Williams, K. R. Grube and R. I. Jaffee

This report concerns the metallurgical characteristics of a lead alloy which is strengthened by two

separate physical reactions: solid-solution hardening and dispersion hardening. The solid-solution hardening addition, 1.5% Cd, improved tensile strength and resistance to slow strain-rate fatigue failure, while the dispersion hardening addition, 0.2% Ni, raised the resistance to creep. Neither addition impaired corrosion resistance. This alloy, according to the authors, can be cast by conventional techniques, and will extrude and roll satisfactorily.

Space-Age Metals — I

Thursday, October 26 – 9:00 a.m.

Effect of Surface Finish on Properties of Beryllium Sheet

by W. V. Ward, C. O. Matthews and M. I. Jacobson

In this investigation, the authors evaluated the effects of as-received, surface-ground, milled, shot-peened, and etched surfaces on mechanical properties of beryllium sheet by tension tests (at room, elevated and subzero temperatures), notched tensile tests, fatigue tests and impact tests. Their results indicated that as-rolled beryllium sheet contained surface defects which lowered ductility. These defects could only be permanently removed by etching (machining merely introduced other defects which were also detrimental to ductility). In all instances, ductility was low, being limited by the presence of notches and preferred orientation. However, heating between 400 and 600° F. raised ductility; the authors indicate that beryllium could be formed in this range "with a reasonable degree of success". Room-temperature tests alone could not satisfactorily discriminate between the various degrees of surface damage because of scatter. As a consequence, the authors suggested that tests conducted over a range of temperatures (impact tests, for example) are better for detecting small differences in the ductility of beryllium.

Influence of Warm Prestressing on the Notch Properties of Several High-Strength Alloys

by E. A. Steigerwald

Notched samples of Vascojet 1000, M300, and B 120 VCA were prestressed above their transition temperatures, the idea being to reduce the notch sensitivity in each grade. Though the technique produced a substantial improvement

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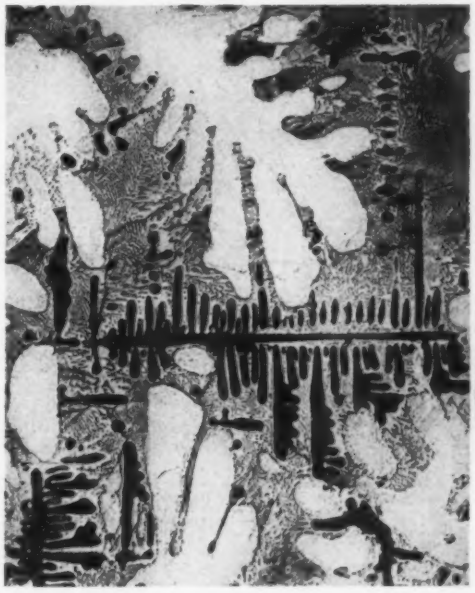

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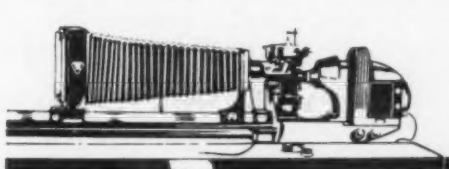

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Circle 1506 on Page 48-B

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Circle 1507 on Page 48-B

Abstracts . . .

(about 100%) in the room-temperature notch properties of the first material, this did not occur in the others, presumably because of the inability to obtain large preload values. Notch properties were apparently improved by the presence of compressive residual stresses at the notch front; these stresses were introduced by prestressing.

Strain-Hardening Properties of High-Strength Sheet Materials

by F. R. Larson and John Nunes

The authors have compiled a large amount of data concerning the true stress-strain properties of several high strength alloys including H11, AM 350, AM 355, Type 301, 4 Al, 3 Mo, 1V, and 6 Al, 4 V (the latter two are titanium alloys). These tests, which were made on sheet specimens at several strength and temperature levels, provided results which were analyzed in terms of strength and strain-hardening property trends previously reported.

Additive Effects of Alloying Elements on the Mechanical Properties of Cast Austenitic Alloys at 1500° F.

by D. L. Sponseller, R. A. Flinn and R. W. Kraft

By investigating the separate and combined effects of boron, carbon, aluminum, molybdenum, columbium, nitrogen and titanium on an austenitic iron-base alloy (18% Cr, 18% Ni), the authors developed a cast heat-resistant alloy which exhibited a 100-hr. rupture strength of 30,000 psi. Nominal composition: 18% Ni, 18% Cr, 0.3% C, 1.25% B, and 5% Mo.

Since as-cast ductility of this alloy was low, the authors experimented with various compositional changes and heat treatments. By altering the nominal composition through lowering carbon and boron (to 0.25% and 0.90%, respectively) and adding 2% W, they were able to produce 4% elongation and 4% reduction in area at room temperature with a 2150° F. soak, followed by air cooling. The resulting 100-hr. rupture strength was 28,900 psi.

Hardness Anistropy of Columbium

by D. L. Douglass

When testing single crystals of columbium by microhardness methods, the author determined that

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Circle 1508 on Page 48-B

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Circle 1509 on Page 48-B

Abstracts . . .

Knoop hardness varied considerably with both the crystal plane tested and the orientation of the indenter within the plane. He concluded that the complex state of stress which existed along with the multiplicity of possible slip systems limited evaluation of deformation to a qualitative basis.

Space-Age Metals — II

Thursday, October 26 – 2:00 p.m.

Constitution and Transformation Behavior of the Ti-8Al-8Zr-1 (Ta + Cb) Alloy

by Harold Margolin and Elmars Ence

For this work, the authors investigated the constitution and the cold working and aging behavior of this titanium alloy. They noted readily discernible structural changes which could be correlated with hardness after room-temperature working and after elevated-temperature exposure.

Investigation of Notch Sensitivity in A-286 Alloy

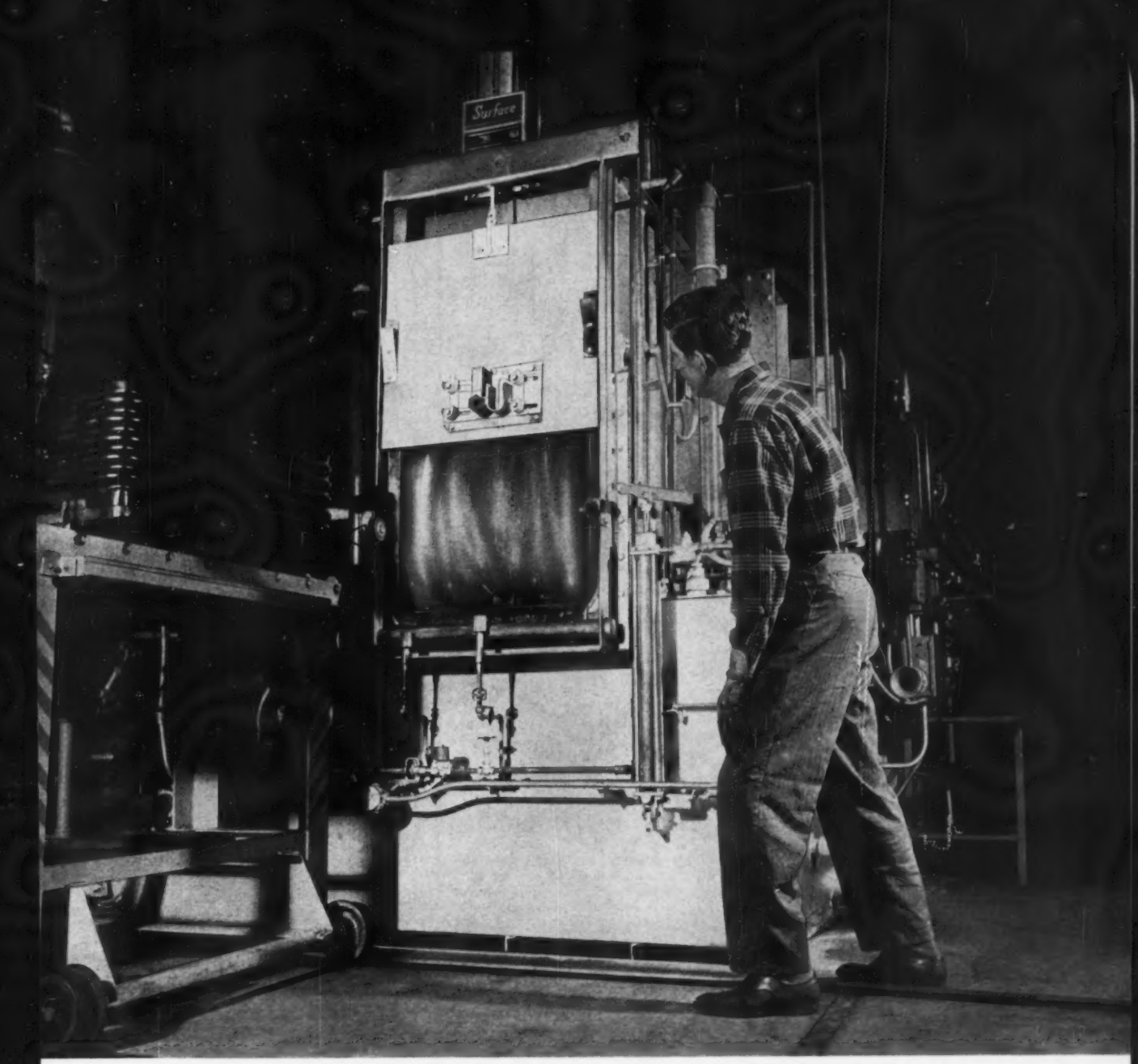
by Gerald B. Heydt

Data obtained in this investigation indicate that notch sensitivity in A-286 is due to a poorly developed cellular type of grain-boundary precipitate which is visible only with an electron microscope, rather than a well-developed cellular precipitate which may be observed at relatively low magnifications. The latter phenomenon was previously thought to be associated with notch sensitivity.

Mechanical Properties of Unalloyed Vanadium

by John W. Farrell

For this paper, the author determined a number of mechanical properties of vanadium as consolidated by consumable-electrode melting, hot extrusion and cold working. The reported data, which were determined for both cold worked and recrystallized material, include short-time tensile properties for bar and sheet from −320 to 2000° F., yield point and strain-aging phenomena, notched-bar tensile properties, true stress versus true strain determinations, the strain-hardening coefficient



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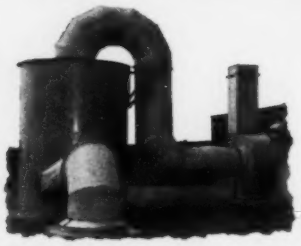

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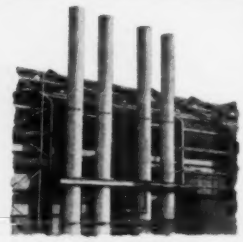

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Circle 1511 on Page 48-B

Abstracts . . .

and exponent, elastic modulus measurements, work-hardening characteristics, bend and Erichsen tests, and crystal orientations.

Effect of Temperature Exposure on the Microstructure of 4.5% Al-3.5% Ti Nickel-Base Alloy

by J. F. Radavich and W. H. Couts, Jr.

In this alloy, $M_{23}C_6$, M_3B_2, TiC, TiN, and gamma prime phases are present, their proportions depending upon the heat treatment. For this investigation, the authors soaked specimens of the material at various temperatures within the 1700 to 1900° F. range, and examined the resulting phases by electron microscope, x-ray diffraction and x-ray fluorescence techniques. Among other items of interest, they found that gamma prime coalesces appreciably at 1900° F., and that deboronization may begin between 1800 and 1900° F. Since it is felt that the loss of boron in heat-resistant alloys would affect rupture properties, ductility, oxidation behavior, and possibly brazing qualities, this study shows the need for careful control of processing.

Corrosion

Thursday, October 26 – 2:00 p.m.

Morphology of Grain-Boundary Carbides and Its Influence on Intergranular Corrosion of Type 304 Stainless Steel

by R. Stickler and A. Vinckier

As revealed by corrosion tests, there was a direct relation between intergranular corrosion behavior and the morphology of grain-boundary carbides; poor resistance was associated with sheets of small carbides and good resistance with isolated dendritic particles. According to the authors, the corrosion is an electrochemical reaction between the carbide particles and the matrix; a sheet of small particles thus provides a continuous path for rapid penetration. Furthermore, the manner of carbide formation is strongly temperature-dependent; isolated dendritic particles are predominant in specimens sensitized above 1350° F., sheets of connected particles appear below 1200° F.

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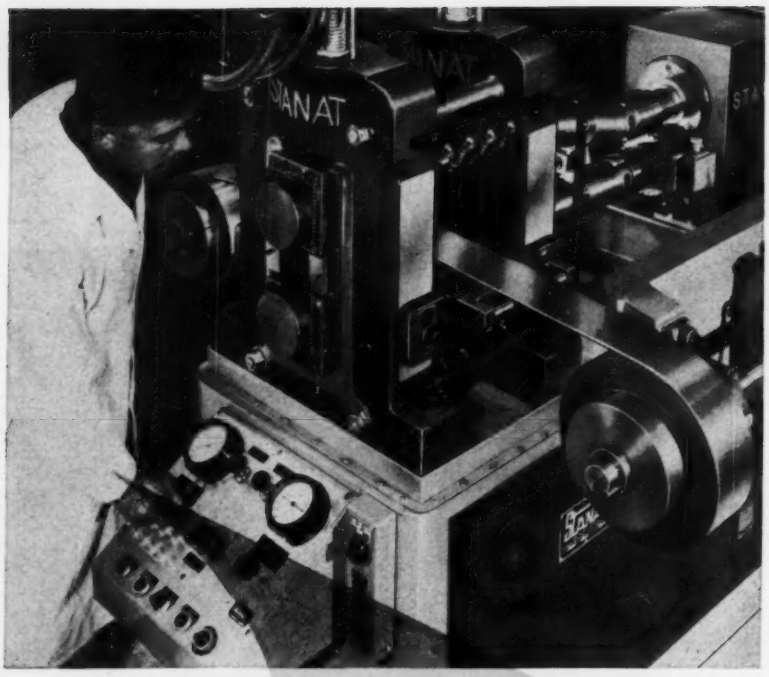

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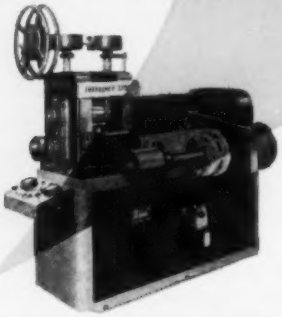

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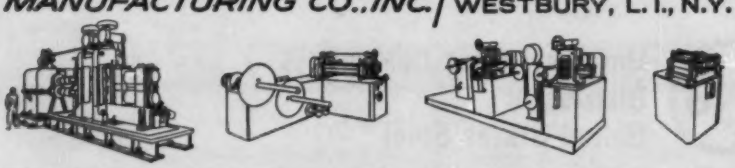

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Circle 1513 on Page 48-S

Corrosion Resistance and Mechanical Properties of Ti-Mo Alloys Containing Noble Metals
by C. R. Bishop and Milton Stern

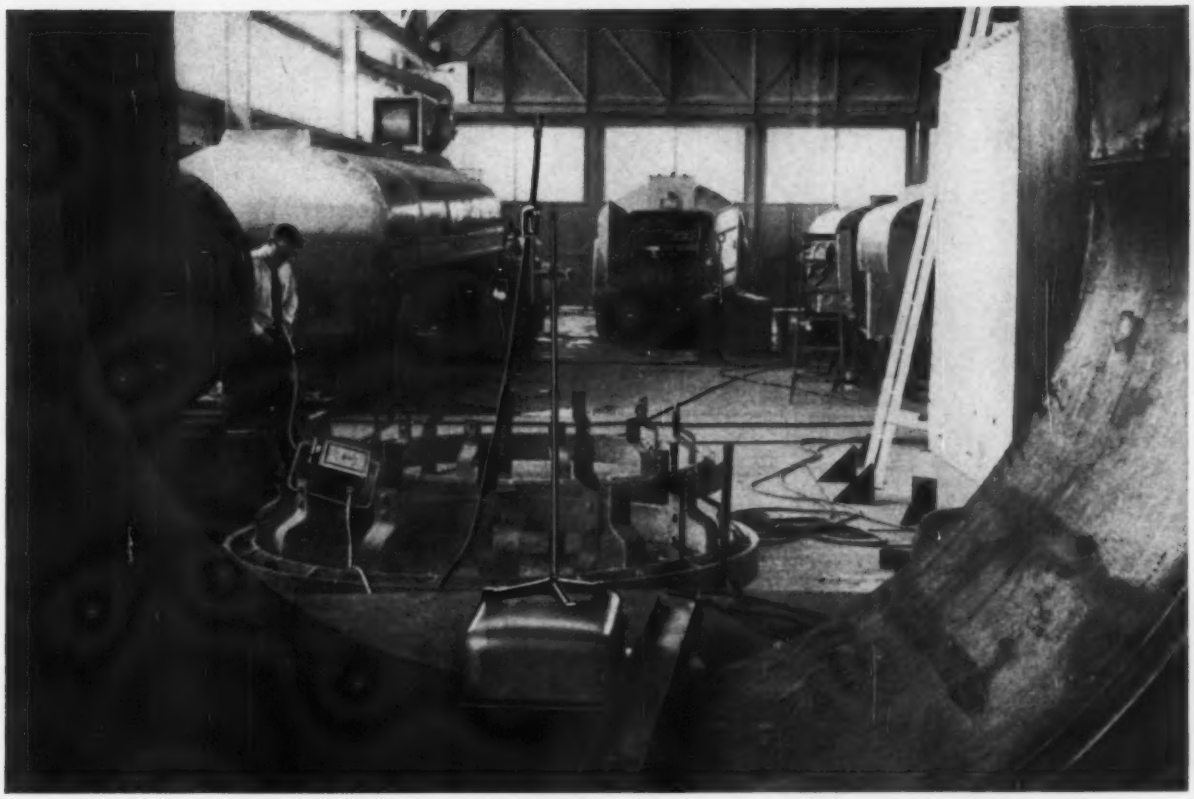
According to the results of this investigation, the natural choice for maximum resistance to oxidizing conditions is unalloyed titanium; however, for highest resistance to reducing environments, titanium alloys containing 30 to 40% Mo are indicated. For the best resistance to both types of corrosive conditions, and for fairly good mechanical properties as well, titanium-base alloys containing approximately 15 to 20% Mo and 0.2% Pd would give the most satisfactory results.

Investigation of the Effects of Fabrication Variables on Corrosion Resistance of Zircaloy-2
by H. S. Kalish and H. M. Cobb

In this investigation concerning the corrosive effect of 750° F. steam at 1500 psi. on Zircaloy-2 in various conditions, the authors found that corrosion resistance was affected by almost all changes in fabrication variables, but that only a few were important. For example, corrosion resistance was aided by secondary vacuum melting, and fewer reheat and conditioning operations during forging. Rolling in the 1450 to 1675° F. range and homogenization treatments appeared to have little effect from a practical standpoint, and a heat treatment at 1900° F. followed by slow cooling was detrimental to corrosion resistance regardless of fabrication and melting technique.

Propagation of Stress-Corrosion Cracking in a Magnesium-Base Alloy as Determined by Several Techniques
by W. M. Pardue, F. H. Beck and M. G. Fontana

In this work, the authors investigated transgranular and intergranular cracking in a magnesium alloy containing 6% Al and 1% Zn by tests conducted in a salt-chromate solution. Their results indicated that transgranular failure was a discontinuous process involving alternate mechanical and electrochemical stages. On the other hand, intergranular failure was continuous and entirely electrochemical in nature. Also, the specimens susceptible to transgranular failure were inherently more brittle than those susceptible to intergranular failure.



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Circle 1514 on Page 48-B

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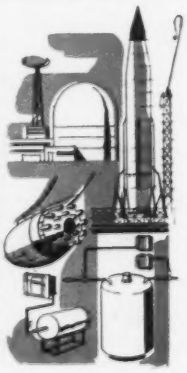

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Circle 1515 on Page 48-B

Processing of Refractory Metals — I

Monday, October 23 – 9:00 a.m.

Protective Coatings for Tantalum and Tantalum Alloys

by W. D. Klopp and H. R. Ogden

Protective coatings of aluminum, chromium, hafnium, silicon, titanium, binary combinations of these metals, zinc, and Al_2O_3 were applied to tantalum, and evaluated for static oxidation behavior between 2200 and 2700° F. As to results, silicon and silicon-rich alloy coatings (produced by pack cementation) protected tantalum and a high-strength tantalum alloy from oxidation at 2700° F. for at least 8 hr. Silicon-aluminum alloy coatings were equally as protective, and seemed to possess limited self-healing properties as well. Aluminum coatings protected unalloyed tantalum to at least 2700° F., but chromium, hafnium, and titanium coatings were not useful above 2200° F.

Development of Oxidation Resistant Coating for Molybdenum

by P. J. Chao and D. K. Priest

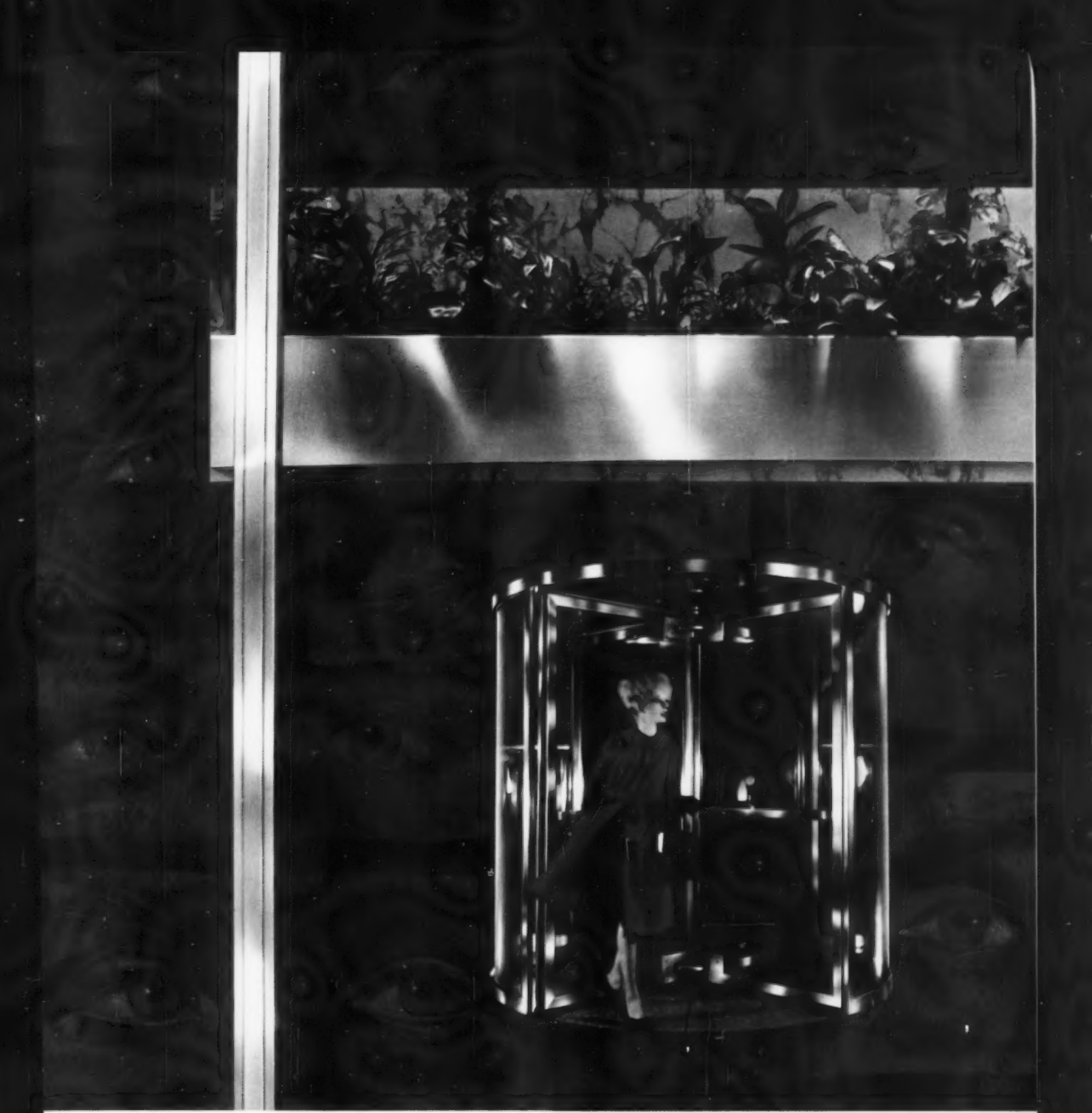
Though molybdenum-base alloys meet the mechanical property requirements of aerospace applications between 2000 and 3000° F., they are limited by their complete lack of oxidation resistance. To answer this need, engineers have developed protective coatings for such alloys, the most advantageous coating technique being the pack diffusion process. However, known techniques do not produce the required coating integrity. As a result, this research was undertaken to devise a desirable and reproducible coating system.

After an extensive screening study of various pack diffusion systems, promising methods were evaluated in detail. Evaluation data for two promising coatings are presented, and scale-up operation, suitability of methods of fabrication of substrates, nondestructive tests and repairability are being investigated.

An Oxidation-Resistant Aluminide Coating on Columbium Alloy F-48

by Stephen Foldes

This is a study of aluminide (Al-11 Si) coatings for short-time oxida-



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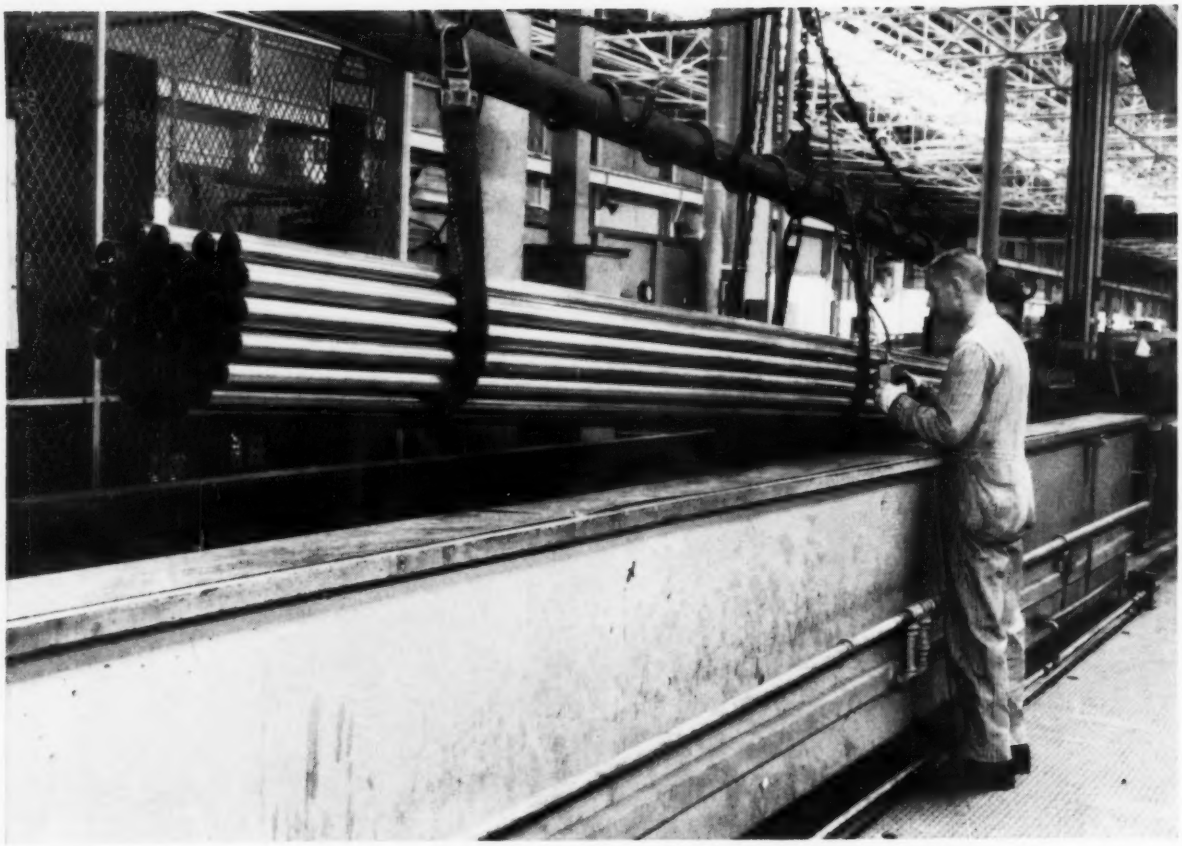

Tubes ready for a Nialk Trichlor degreasing bath at Wolverine Tube Division of Calumet & Hecla, Inc., Decatur, Alabama.

HOW WOLVERINE TUBE CUTS DOWN DEGREASER CLEANOUTS

Cleaning the inside of a one-inch by thirty-foot copper tube sets up a problem.

Yet Wolverine Tube, Division of Calumet & Hecla, Inc., removes dirt and chips from these and gets them immaculate while maintaining widely spaced cleanout schedules.

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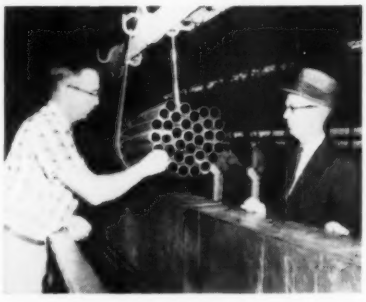
It keeps the bath from going acid, even with bits of metal in it. And it lets Wolverine use baths for tube operations three months before cleanout.

The tubes are cleaned at many stages. "We cannot use a solvent that might stain the walls of the tubing," says Dalton F. Jackson, metallurgist in the technical section. "Nialk Trichlor does not stain."



D. F. Jackson (L) of Wolverine and W. H. Ames (R) of Wittichen Chemical Company, Birmingham, Alabama, distributor for Nialk Trichlorethylene, examine degreased tubing.

Wolverine finds the system of degreasing tubes in vapor of Nialk Trichlor and then spraying them with pure condensate of the same solvent highly efficient.

The contaminated solvent from the degreaser is distilled and re-used. "Even after distilling it many times, Nialk still maintains a highly effective degreasing potential," Jackson says.

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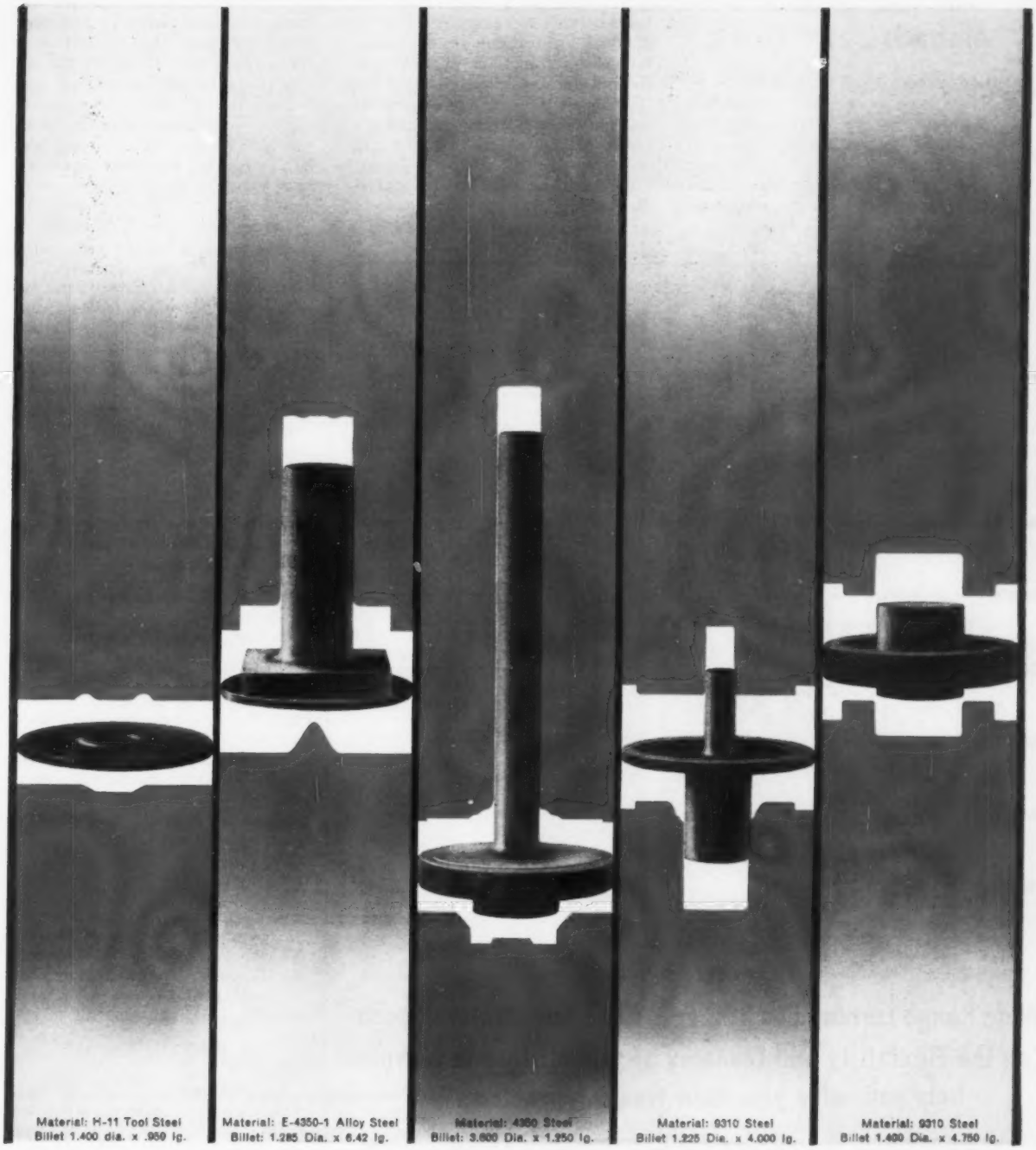
Circle 1516 on Page 48-B


Material: H-11 Tool Steel
Billet 1.400 dia. x .950 lg.
Material: E-4350-1 Alloy Steel
Billet: 1.285 Dia. x 6.42 lg.
Material: 4350 Steel
Billet: 3.600 Dia. x 1.250 lg.
Material: 9310 Steel
Billet 1.225 Dia. x 4.000 lg.
Material: 9310 Steel
Billet 1.400 Dia. x 4.750 lg.

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GENERAL DYNAMICS | ADVANCED PRODUCTS DEPARTMENT

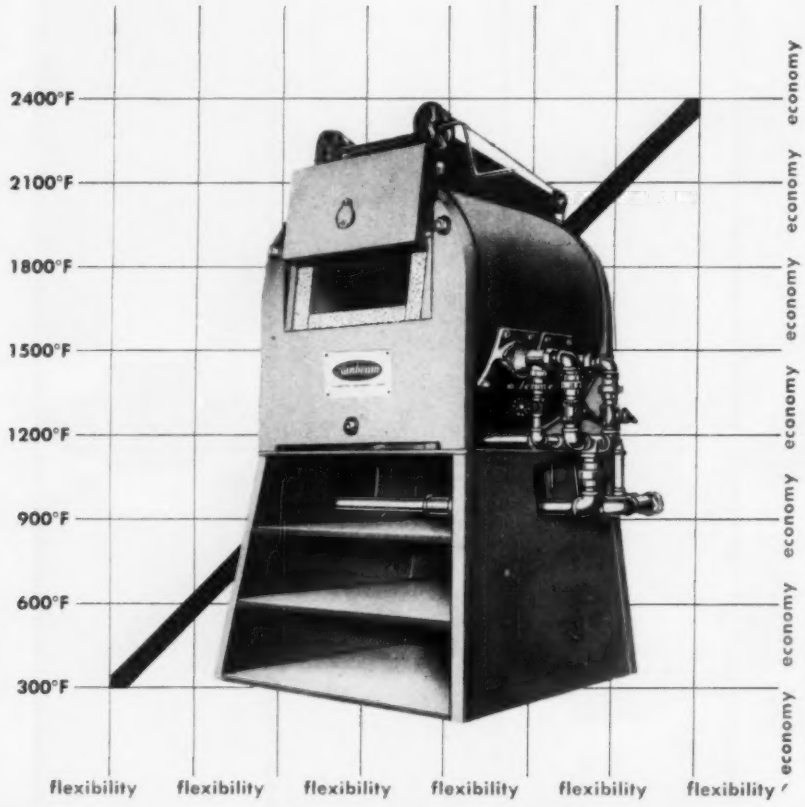
Circle 1517 on Page 48-8

Abstracts . . .

tion protection of F-48 at 2500° F. They were applied by: (*a*) electroplating the alloy with silver; (*b*) enriching the surface with titanium by diffusion; and (*c*) incorporating silver in the 11% Si aluminum alloy. Of the three, the silver electroplate-aluminide coating combination was best; it protected F-48 for 10 hr. at 2500° F. Furthermore, the room-temperature ductility of this plate did not drop after oxidation.

Detailed studies were carried out on silver plate-aluminide coatings. On oxidation at 2500° F., $CbAl_2$ appeared at the coating-metal interface, and the main constituent of the coating was established (by x-ray diffraction) as $CbAl_3$. Although there was no evidence of a distinct silver-rich phase at the interface of the coating and metal in the as-applied or oxidized condition, concentrations of silver and silicon existed in the coating near the $CbAl_2$ interfacial layer. The coating also had excellent oxidation resistance and was able to cover fairly sharp corners.

During this research, the oxidation resistance of selected Cb-Al alloys was also surveyed. Increasing the aluminum content improved the oxidation resistance, but reduced ductility. Additions of Ti + Cr and Ti + Si decreased the aluminum content required for an equivalent oxidation resistance in alloys devoid of titanium, with a concomitant improvement of ductility.



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Circle 1518 on Page 48-B

Properties of the Refractory Metals Sprayed Under Controlled Environment

by M. A. Levinstein

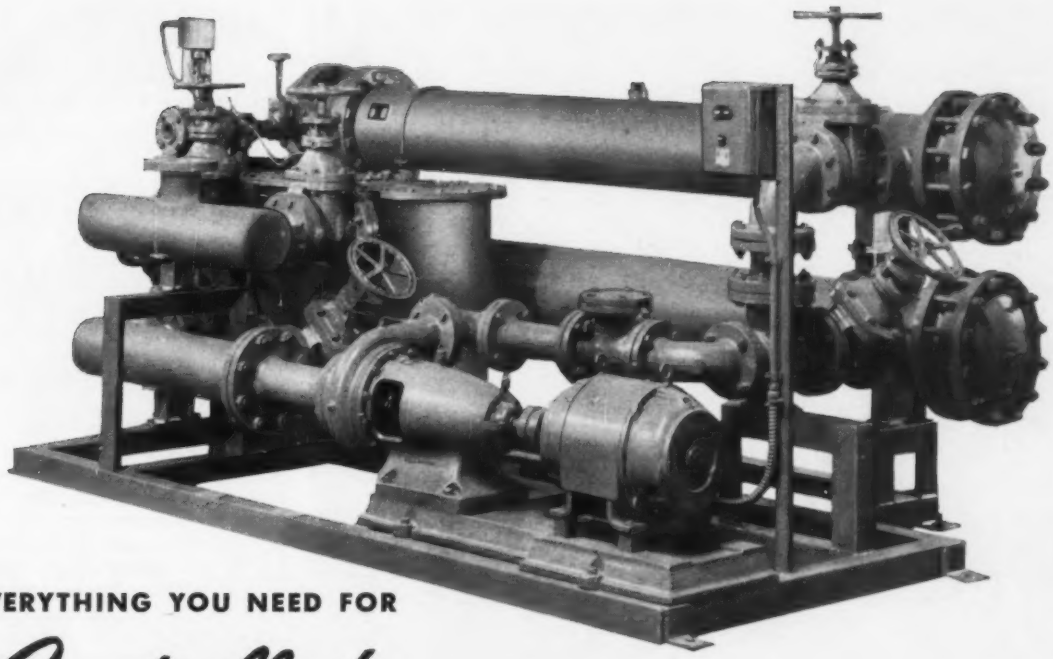
In this paper, work performed on tungsten, molybdenum, tantalum, and columbium is covered. The equipment setup for spraying under controlled environment condition is described, and sample preparation and configuration are discussed. The results concern mechanical properties up to 4500° F., microstructures of the deposits, and effects of alloying additions.

Some Observations on the Infiltration of Porous Structures of Molybdenum, Tungsten and Their Carbides with Copper in Vacuum and in Hydrogen

by H. H. Hirsch

For this study, pressed bodies of molybdenum, tungsten, MoC and WC were infiltrated with zone-refined and OFHC copper, the greatest emphasis being placed on W-Cu composites. Infiltrations were carried out in atmospheres of vacuum, hydrogen and combinations of the two.

Thoroughness of infiltration was influenced by the atmosphere, heat treatment and supporting material. After obtaining total gas content of the infiltrated bodies, it was correlated with the atmosphere, heat treatment and type of copper. A recommended procedure is given for good infiltrations with low gas contents.



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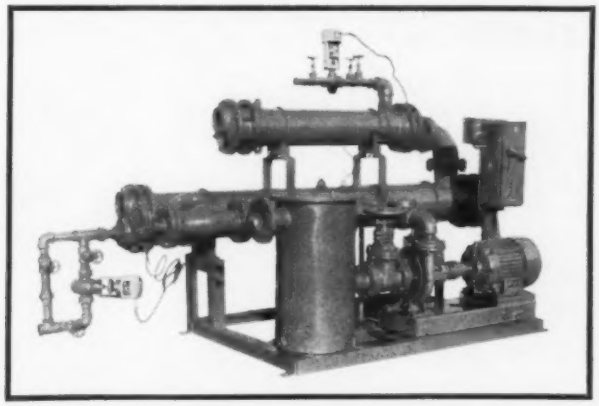

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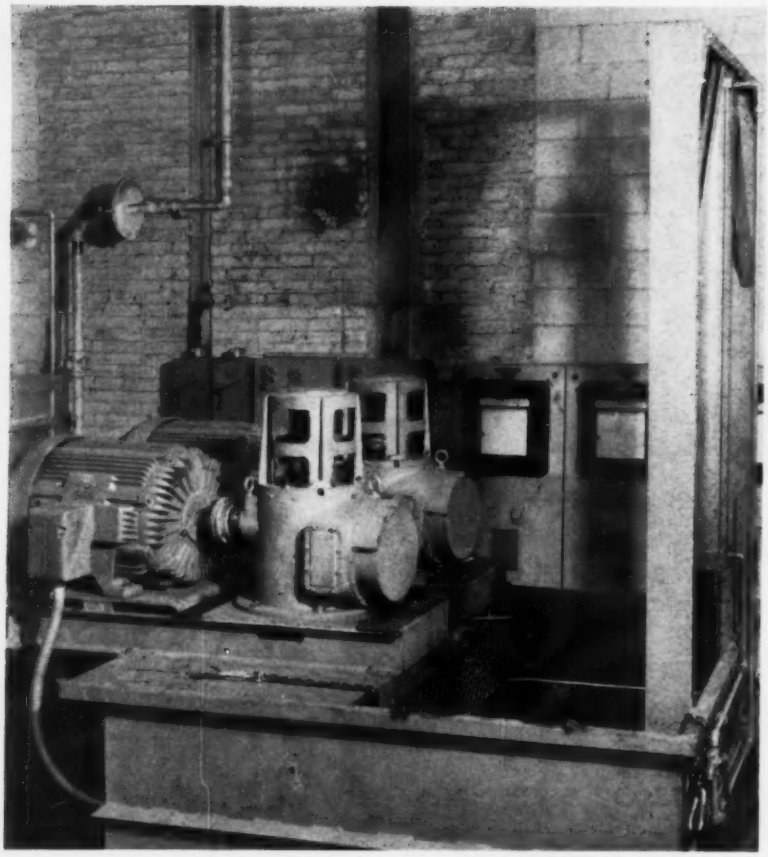
Circle 1519 on Page 48-B



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Circle 1520 on Page 48-B

Abstracts . . .

A Study of Brazing Alloy Systems for Joining Columbium-Base Alloys

by W. R. Young and E. S. Jones

To form columbium alloys into components, brazing is desirable as a joining technique. The present study, undertaken to identify promising brazing systems, concerned two types of columbium alloys. One base alloy, with 1 Zr, was chosen as being representative of the low-strength, easily fabricable alloys, while F-48 alloy (15 W, 5 Mo, 1 Zr) represented the high strength, more-difficult-to-fabricate alloys.

Since the expected applications of these columbium alloys involved two temperature regimes (to 2500° F. for F-48 and 1800 to 2200° F. for 1 Zr columbium alloy), brazing systems were selected for each temperature range. Several binary alloy systems based on titanium, zirconium, vanadium, tantalum, and columbium exhibited appropriate melting temperatures. As a result of this study, the authors identified brazing alloy systems which showed promise for use in joining columbium alloys for service in the 2000 to 2500° F. range. Ternary alloys may have even more attractive possibilities.

Theory of Work Hardening

Monday, October 23 – 9:00 a.m.

(No abstracts available)

Effects of Surface and Environment on Strength — I

Monday, October 23 – 9:00 a.m.

Interaction of Surface and Strength Phenomena

by E. S. Machlin

The state of surface may affect flow and fracture strengths by (*a*) influencing the rate of escape of dislocations through the surface, (*b*) influencing the motion of dislocations that intersect the surface, (*c*) affecting the energy of newly formed surfaces at crack spearheads, and (*d*) altering the elastic constants for a sufficient distance from the surface to affect dislocation generation.

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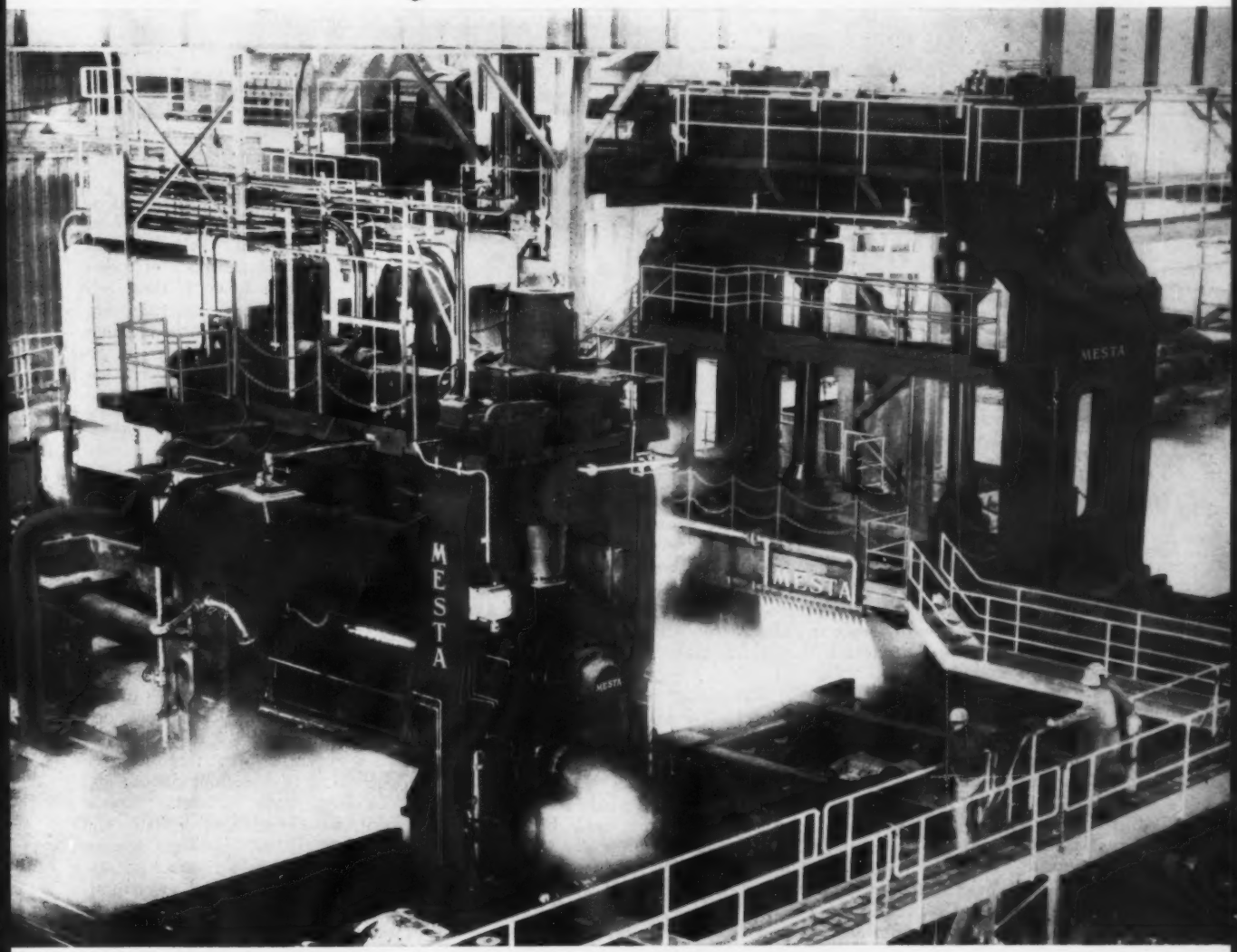

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Circle 1521 on Page 48-B

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says J. W. Diener, AMP metallurgist

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Circle 1522 on Page 48-B

Abstracts . . .

Examples of these effects are cited, the areas where insufficient precise experimentation exists are listed, and suggestions are made for future research.

Recent British Thin Foil Experiments

by John Silcox

New techniques are discussed in this paper. For example, when dislocations move, contrasts left behind (they appear in films) can be interpreted in terms of images of dislocations remaining at the surface of the thin foil. It is also possible to employ the slip trace contrast to study the rearrangement of dislocations during thinning.

Stresses in Overgrown Films on Crystalline Substrates

by N. Cabrera and J. H. van der Merwe

In this paper, the authors calculate the energies connected with an interface between a crystalline film and a crystalline substrate of a different substance. Since, in these calculations, interfacial spacings are considered to differ in one direction only, the interfacial contact can be analyzed in terms of a row of edge dislocations with Burgers vectors in the interface.

An Electromechanical Effect in Semiconductors

by J. H. Westbrook and J. J. Gilman

According to this work, the resistance of semiconducting crystals to indentation deformation is lowered significantly (up to 60%) by the simultaneous presence of a small potential (0.05 to 10 v.) between the indenter and the crystal surface. This electromechanical effect appears to be confined to the plastic strain region of a surface layer of material, 2 to 3 microns deep.

A large body of varied experiments have established that the effect is real, similar effects having been observed in a number of different semiconductors (germanium, silicon, InSb and SiC), but not in metals or ionic crystals. The effect, which disappears at elevated temperatures, but becomes enhanced below room temperature, is not sensitive to the type of current carrier.

The role of surface preparation, crystallographic orientation, kind

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

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Tests for Determining Mechanical Properties of Alloy Steels

The types of tests used to evaluate the mechanical properties of an alloy steel depend upon the end use of the steel involved. Mechanical properties are determined usually by tension, bend, and hardness tests, and by a group of special tests employed on tubular and wire products.

(1) *Tension tests* provide means of determining tensile strength, yield point, yield strength, proof stress, proportional limit, per cent elongation, and per cent reduction of area. This sort of test subjects the steel to stresses resulting from the application of an axial tensile load to the specimen ends, the load being sufficient to rupture the specimen.

(2) *Bend tests* often aid in determining the ductility of steel. The severity of such a test depends largely upon the bending radius used. Several factors influence the length of radius, including thickness of the test specimen, width of test specimen, direction of test, chemical composition, tensile strength of specimen, etc.

(3) *Hardness tests* determine the steel's resistance to penetration. This characteristic is most commonly measured by the Brinell Test or the Rockwell Test. In the former, pressure is applied to the surface of a test specimen by means of a ball 10 mm in diameter. Two diameters of the resulting impression are measured and averaged; the average is converted to the hardness number by means of a conversion table. In the Rockwell Test, the degree of hardness is read on a gage; hardness is measured by the penetration of a diamond point or a 1/16-in. steel ball. Rockwell "C" scale readings are used in connection with the diamond point; "B" scale in connection with the steel ball. The "C" and "B" are the most commonly used of the several Rockwell scales.

(4) *Special additional tests* are often made on tubular and wire products. These include such items as hydrostatic and manipulating tests, and torsion and wrapping tests, the latter two being used only with wire.

The subject of testing and its relationships to the end uses of alloy steels has been given broad study by Bethlehem metallurgists. If you desire, they will be glad to discuss any phase of it with you, and also give unbiased opinions on such matters as analysis, proper selection of steels, machinability, etc. Call for their services at any time.

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Circle 1523 on Page 48-B

footenotes on the art of producing higher-quality steels

SUBJECT:

silicon

Its behavior in quality steels

Silicon is one of the most common alloying and process elements used in steel. There are three properties of Si utilized in steel production.

(1) Silicon is a moderately powerful deoxidizer.

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(3) In low carbon steels, it increases electrical resistivity and is an aid to formation of large, well-crystallized ferrite grains.

The increased strength of steels containing high silicon has made the 9200 series a popular choice for spring steels. However, much of this tonnage is being replaced by the high-chromium 5100 series.

The modern electrical industry would not be possible without electrical sheet and strip steels. Silicon contents up to 5% are used in this application. When annealed, high permeability is obtained.

Electromanganese Lowers Silicon Content to Improve Ductility

However, one drawback to use of silicon as an alloy of steel is its adverse effect upon ductility. In sheets or bars where extreme ductility and good physical properties are needed, aluminum is commonly used as the deoxidizing agent.

One of the benefits obtained from the use of electrolytic manganese is extremely low silicon content. With the ever-increasing demand for better ductility in sheet steels, more and more producers are using electrolytic manganese in sheet applications.

Electromanganese Removes Five Trouble Makers from Electrical-grade Steels

Electrolytic manganese is also used in electrical sheet steels. Here, of course, low silicon is not the desired benefit. However, electrolytic manganese contains only traces of carbon, sulfur, oxygen and nitrogen, all of which are detrimental to electrical properties. When the Hydrogen-Removed grade is used, another potential source of trouble is eliminated. Another benefit of the pure manganese addition is that the formation of large ferrite grains will not be hindered by dispersions of fine non-metallic inclusions.

For more details on Foote Electromanganese®, write for Bulletin 201, Foote Mineral Company, 424 Eighteen West Chelten Ave., Phila. 44, Pa.

FOOTE MINERAL COMPANY

Circle 1524 on Page 48-S

Abstracts . . .

and concentration of charge carrier, geometry, and time have also been examined. All of this work is extensively documented and discussed, but no satisfactory model or mechanism has yet been conceived.

Influence of Thermal-Mechanical History on the Embrittlement of Aluminum Alloys by Mercury

by H. Nichols and W. Rostoker

Liquid mercury embrittles all aluminum alloys to some degree; certain high-strength alloys are so embrittled that failure occurs at less than 20% of the yield stress. Intrinsic strength of the alloy itself is not the dominant factor. Furthermore, pure aluminum, even though it may be restrained from yielding to very high stress levels as in Alclad, is not measurably embrittled. As for details, 2024 alloy in the overaged state does not become more embrittled, even though cold rolled 95% to strength levels as high as those of the age-hardened condition. The most severely embrittled state is the fully aged condition with the superposition of a small amount of cold work. With much cold work there is some recovery of strength.

High-Purity Iron and Its Dilute Solid Solutions — I

Monday, October 23 – 9:00 a.m.

(No abstracts available)

Processing of Refractory Metals — II

Monday, October 23 – 2:00 p.m.

Processing and Properties of Arc-Cast Tungsten Sheet

by C. P. Mueller and W. J. Schoenfeld

In producing high quality arc-cast tungsten sheet in large sizes and thin gages, processing problems have been judged, and a realistic approach has been taken in manufacturing the desired product. Recrystallization and mechanical property data have been obtained for various sheet thicknesses, and present size limitations (as well as possible solutions for them) have been evaluated. A method for producing 36 by 96 in. sheet is presented.

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THIS NEW PACIFIC DESIGNED FURNACE BRAZES THRUST CHAMBER OF THE F-1 ROCKET ENGINE—and avoids the prohibitive height of an enlarged bell furnace which would have required an extremely tall structure to permit it to be lowered and raised. Pacific Scientific engineers—working in close cooperation with Rocketdyne personnel—developed a unique design that utilizes a common base for heating and cooling. This new brazing concept permits the two gas heating sections to move on rails to surround the air-tight retort containing the large unbrazed thrust chamber. Brazing completed, the heating sections withdraw and the two watercooled sections move in to speed the cooling process. **Less than 40 seconds are needed to change from the heating to the cooling cycle.** Furnace temperatures and atmospheres—argon, nitrogen and hydrogen, in any sequence—are rigidly controlled from a special console panel as are all other operations. Standing 25 feet tall with a diameter of twenty feet, this new brazing furnace is installed at Rocketdyne, a division of North American Aviation, Inc., Canoga Park, California. As another FIRST for Pacific Scientific—it is the world's largest brazing furnace of its kind—either electric or gas fired. For further information on this—and other Pacific designed and built furnaces, write today to **PACIFIC SCIENTIFIC COMPANY, P. O. Box 22019, Los Angeles 22, California.**

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Circle 1525 on Page 48-B

Abstracts . . .

Arc Melting and Hot Workability of Tungsten Alloys

by R. G. Carlson

This report concerns studies on the hot workability of tungsten alloys containing titanium, zirconium, silicon, aluminum, tantalum, carbon and boron. The author found that the hardness of tungsten was not greatly affected by any alloying addition except zirconium – 0.5 at. % Zr reduced the as-cast hardness (for unalloyed tungsten, Rockwell A-64) to Rockwell A-58.4. Furthermore, in decreasing order in the ranges investigated, boron, carbon, silicon, and zirconium promoted grain refinement in the ingots, and the solubility of boron in tungsten was between 5 to 10 ppm. The hot workability of tungsten could be increased by adding carbon and boron, particularly the latter. In fact, the recrystallization temperature of the rolled material was increased 150° C. (270° F.) by the addition of 0.5 at. % (0.029 wt. %) B. Carbon additions, however, did not greatly increase the recrystallization temperature of 1250° C. (2280° F.) at the 50% recrystallization level for undoped tungsten sheet.

Evaluation of Variables Related to the Production of Arc-Cast Molybdenum Alloy Sheet

by W. A. McNeish

This report concerns a comprehensive study which was conducted to determine the effects of consolidation practice and primary fabrication on the quality of sheet bar and subsequent sheet product. Research covered the effects of variations in ingot diameter, single versus double melting, direct forging (in an argon atmosphere), direct extrusion, and combinations of these operations. Sheet properties obtained for Mo+0.5%Ti and Mo+0.5%Ti+0.1%Zr are fully analyzed.

Processing and Properties of Molybdenum Mill Products Produced from Massive Isostatically Pressed and Sintered Billets

by L. L. France and F. P. Giannakos

Beginning with a brief description of isostatic pressing and sintering techniques used to form molybdenum powder into the starting billet, this report discusses resultant billet properties and inspection techniques. Processing procedures are described for the production of sheet of various gages. Also given are the as-rolled and stress-relieved tensile and bend properties, and a comparison between sheet and bar produced by powder metallurgy techniques and arc-cast techniques.

Effect of Microstructure on the Workability and Properties of Vacuum Hot Pressed Columbium Alloy

by T. L. Robertshaw, R. G. Frank and I. Perlmutter

Prealloyed powder of F-48 composition was vacuum hot pressed under various processing cycles. Although finer powders, higher temperatures, and longer times yielded dense billets of fine grain size, microstructural changes occurring during compaction inhibited ductility. Deleterious grain-boundary precipitates, formed at the higher temperatures and longer times, could be traced to interstitial content of powder charges. Rollability, and hence ductility, was enhanced by compaction of pure powders above a threshold density and below 3700° F. This report also compares mechanical properties with those obtained from two other consolidation techniques.

Techniques for the Preparation of High-Purity Refractory Metals

by E. Fenn, M. Badiali, and R. Bakish

This paper describes the preparation of high-purity molybdenum, tungsten and tantalum by distillation, sublimation and zone refining of the halides prior to hydrogen reduction. Also discussed are equipment used, processing variables, and experimental results. Finally, the authors attempt a correlation between analytical data and processing variables.

Strength of Sintered Nickel-Tungsten

by J. H. Brophy, H. W. Hayden and J. Wulff

For this report, transverse rupture strengths of sintered compacts of tungsten containing small amounts of nickel have been correlated with the mode of powder preparation, density, and nickel content. Sintering times ranged from 1 to 16 hr. at 1000 and 1100 C. (1830 and 2000° F.) As for results, in specimens containing 0.25% Ni, strength increased with density during the

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For more information see the opposite page . . .

Westinghouse

Circle 1526 on Page 48-B

initial stage of the sintering process. In the final stage, however, strength dropped with the onset of grain growth. Strength rose with increasing nickel contents up to 4%, presumably because grain growth was restricted. The maximum strength observed was 73,000 psi. (in three point loading), a figure comparable to that obtained with massive tungsten recrystallization in the presence of nickel and tested in the same way. The results were sensitive to the mode of powder treatment, and ductility was negligible in all instances.

Effects of Surface and Environment on Strength — II

Monday, October 23 – 2:00 p.m.

Interaction of Surfaces and Dislocations

by A. K. Head

This report concerns a theoretical analysis of the manner in which the surface of a solid influences the properties of dislocations. In particular, it considers the effect of a surface film in impeding the escape of dislocations from the solid, and the dependence of this blocking effect on the properties of the surface film. For example, the properties of a dislocation in a thin film will differ significantly from those of a dislocation in a bulk solid. Also, such a dislocation may cause the thin film to bend or buckle. Along with estimating the magnitude of these deformations, the author discusses the possibilities for observing them.

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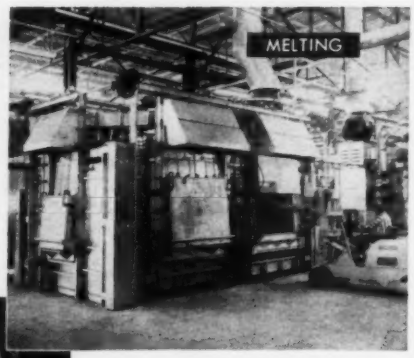

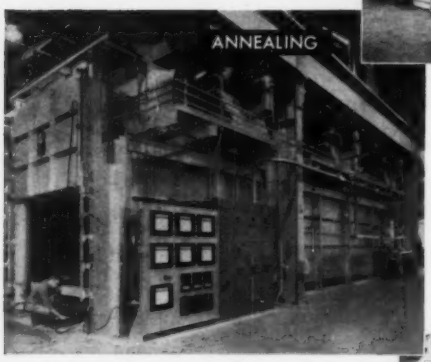

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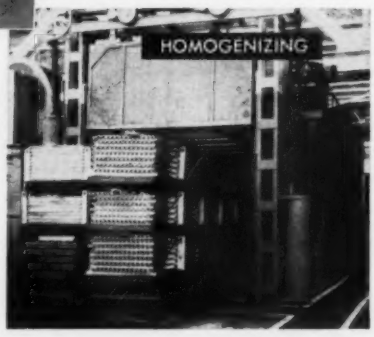

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Circle 1527 on Page 48-B

Variation of the "Barrett Anomalous After-Effect" with Torsion

by D. B. Holt

In this study of the variation of the magnitude of the transient in the "Barrett abnormal after-effect" with torsional strain, the results provided evidence that the transient takes but a short time in a small twist region; in a large twist region it takes much longer. The effect of the anodizing time on the structure and properties of the film was also studied; all results are discussed in terms of dislocation theory.

Effect of Surface on the Mechanical Deformation of Metal Single Crystals

by I. R. Kramer

For this research, single crystals of aluminum and gold were pulled in tension while the surface layers were removed continuously by an electrolytic polishing bath. The results indicated that "debris" formed in regions near the surface of the crystal during deformation to impede the passage of dislocations.

Polycrystalline specimens of aluminum were also pulled in tension while the surface layers were removed. They behaved much like single crystals in that the slope of the stress-strain curve dropped throughout plastic deformation as the rate of metal removal increased.

The author also studied the tensile behavior of single crystals of aluminum and copper in nonpolar solvents containing surface-active agents. Results led to the belief that the changes in the deformation characteristics were associated with the formation of metal soaps and the rate of solution of the soaps in the solvent. Though the creep behavior of gold single crystals in paraffin oil was not affected by the addition of oleic acid or octanoic acid, it was increased markedly when the sur-

Computer Analyses Now Make Tenzaloy Better Than Ever

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Asarco has introduced another significant advance in aluminum casting alloy technology — computer correlation of composition and properties of its widely used high-strength, self-aging Tenzaloy. Results: Further refinement in quality and reliable performance of this superior alloy.

Data for the pioneering computer analyses were drawn from a long record of properties and composition of Tenzaloy plant heats compiled by Asarco's Central Research Laboratories. From these studies has come new knowledge of the interaction of Tenzaloy elements and effects of alloying ingredients on mechanical properties.

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Elongation (in 2")	4-5%	6-7%
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Burroughs B205 computer correlates unique composition and properties of Asarco's high-strength Tenzaloy.

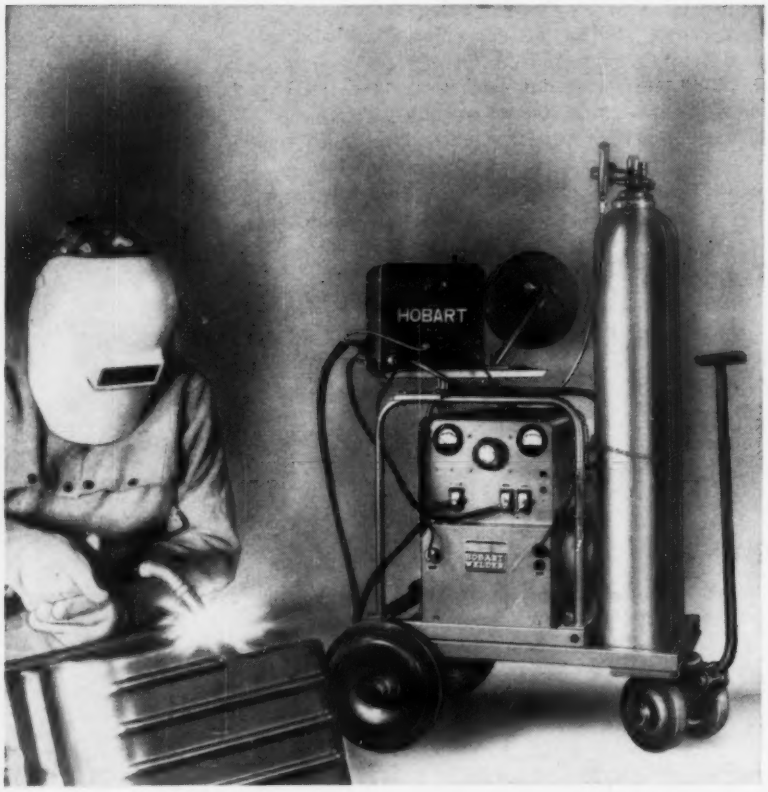
face layers were removed continuously by an electrolytic polishing bath.

Role of the Surface on the Strength, Ductility and Embrittlement of Metals

by A. Berghezan

Previous work has shown that the nucleation of dislocations in the surface plays an important part in the deformation process. Furthermore, since the surface influences the rate at which inner dislocations flow out of the material, any transformation of the surface layer should influence the mechanical properties of the metals in two ways; by influencing the nucleation of slip in the surface and by the barrier action of the surface layer to the outflow of dislocations generated inside the crystal.

On the basis of the above observations, the mechanical properties have been measured on some pure reactive and refractory metals possessing either a clean surface or one contaminated to different degrees by introducing interstitial oxygen to different depths into the surface. According to results, this oxygen embrittled the material by building up a hard, brittle layer on the surface. This effect is being studied with titanium, columbium, and tungsten, and other interstitial elements, particularly carbon and nitrogen, are also receiving attention.



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Circle 1529 on Page 48-B

High-Purity Iron and Its Dilute Solutions — II

Monday, October 23 – 2:00 p.m.

(No abstracts available)

Titanium in 1975

Tuesday, October 24 – 9:00 a.m.

(No abstracts available)

Continuous Casting

Tuesday, October 24 – 9:00 a.m.

(No abstracts available)

Effects of Surface and Environment on Strength — III

Tuesday, October 24 – 9:00 a.m.

Some Effects of Adsorbed Polar Molecules on the Etching and Yielding Behavior of LiF Crystals

by A. R. C. Westwood

Aqueous solutions of long-chain fatty and perfluoro-acids will etch LiF crystals to reveal points of dislocation emergence and other surface features of interest. These etchants are being used to study the cross-gliding of screw dislocatons at the surfaces of crystals in inert and surface-active environments.

On the basis of observations, the author suggests that chemisorbed polar molecules restrict and control the motion of cross-gliding screw dislocations. Compression and bending experiments revealed that adsorbed polar molecules increase in yield and shear stresses before inducing the lower rate of work hardening known as the "Rebinder" effect. The author also presents possible explanations for the etching and mechanical behavior.

How would you anneal these 5 types of alloy wire?

The various types of alloy wire in this photograph are manufactured for specialized applications by the Riverside-Alloy Metal Division, H. K. Porter Company, Inc. They range from stainless steel, for aircraft industry use, to monel metal and an iron-nickel-cobalt alloy with thermal expansion characteristics suitable for sealing to hard glasses. Annealing temperatures range from 1450 to 2150 F, close control being necessary to maintain wire quality, measured by elongation, grain structure and tensile strength. The wire is annealed continuously—normally in a disassociated ammonia atmosphere.

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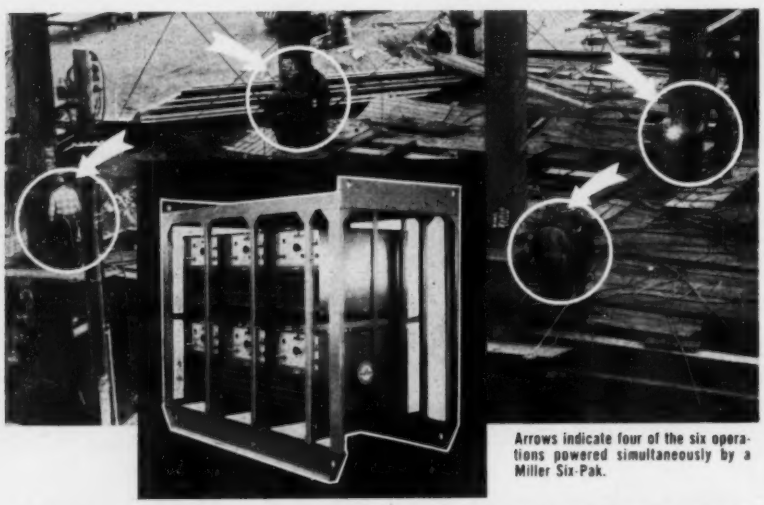
Circle 1530 on Page 48-B

Abstracts . . .

Effect of Surface Condition on the Mechanical Properties of Polycrystalline Ionic Solids

by R. J. Stokes

Ionic solids of the rock salt structure belong to the semibrittle class of solids – they can deform plastically, but are completely brittle if small defects are present. To illustrate this point, the strength and ductility of single and polycrystalline magnesium oxide are compared for three different surface conditions. When the surface is "perfect" (chemically polished and handled so carefully that only the strongly locked grown-in dislocations remain), both single crystals and bicrystals are extremely strong, over 100,000 psi. Fracture occurs when microcracks suddenly generate at the onset of plastic deformation (in single crystals at slip band intersections; in bi-crystals at the grain boundary). Next, if the surfaces of single crystals contain fresh dislocations only, they are relatively weak (around 10,000 psi.) and ductile. Ductility depends upon the density of slip since the size of a microcrack formed at a slip band intersection is dictated by slip band spacing. Finally, when surfaces contain both fresh dislocations and microcracks, single and polycrystalline specimens are weak and brittle due to the propagation of surface defects.



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Circle 1531 on Page 48-B

Effect of Controlled Surface Contamination on the Ductility of Ionic Crystals

by G. T. Murray

One of the major sources of atmospheric embrittlement in rock salt is the formation of a $NaClO_3$ surface layer during exposure to air, oxygen, or ozone. This work was initiated to determine whether MgO crystals also embrittled in the same manner.

Chemically polished MgO crystals were exposed to varying pressures of air, O_2, N_2, argon, CO_2, and moisture at temperatures ranging from 25 to 250° C. (75 to 480° F.) for periods up to several days. Subsequent bend tests, conducted over a wide temperature range, failed to show embrittlement in the MgO crystals even when clearly visible deposits were present. However, in one instance, a crystal which had become coated (with polycrystalline MgO) embrittled.

Experiments are in progress on the effect of exposures to gases at elevated temperatures, the influence of gases on samples containing surface flaws, and on the mechanism of residue (redeposited MgO) embrittlement.

Effect of Environment on High-Temperature Strength of Metals

by M. R. Achter

At elevated temperatures, the strength of metals in vacuum or inert gases may be either higher or lower than that measured in a reactive gas. According to the mechanism suggested for this reversal of the atmosphere effect, adsorption of gas facilitates crack propagation while oxidation and similar reactions harden and strengthen a metal, the controlling process being determined by temperature and stress. This report concerns current studies which

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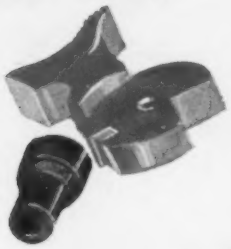

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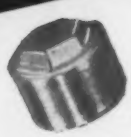

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Circle 1532 on Page 48-B

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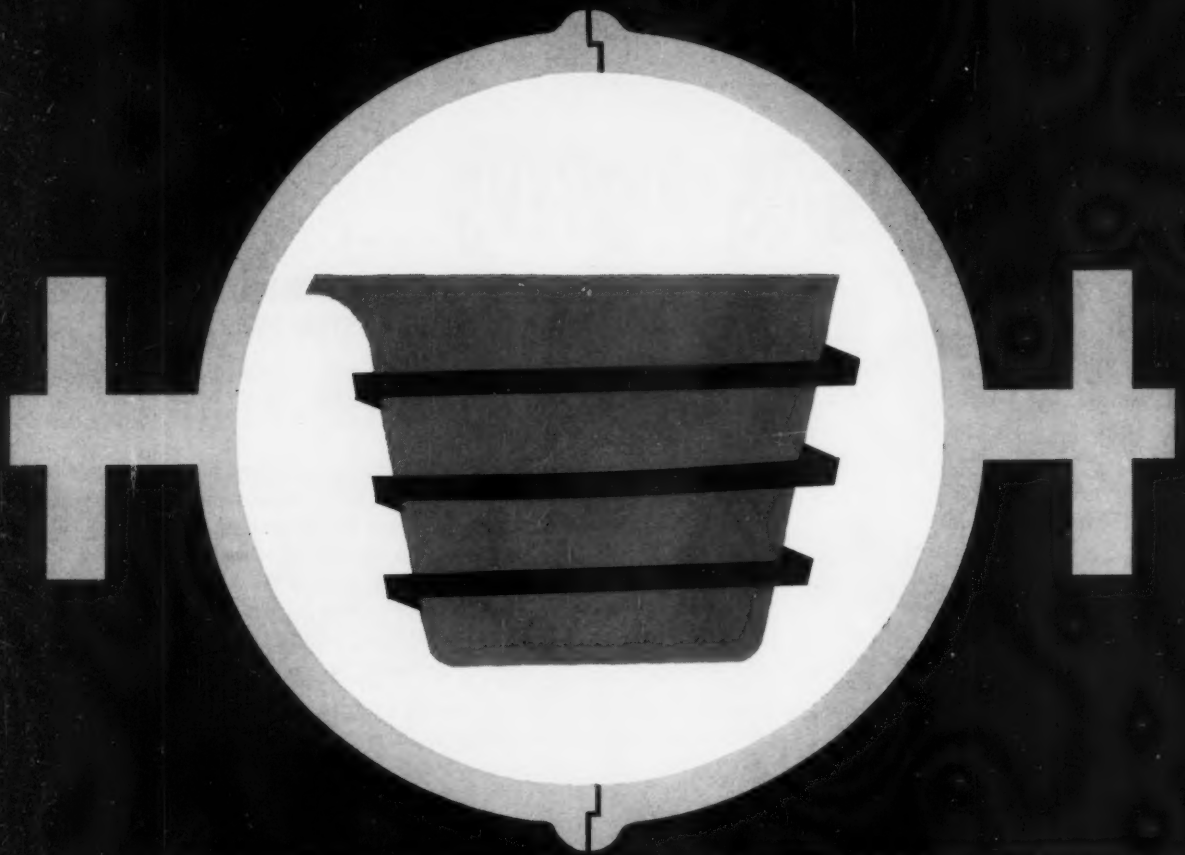

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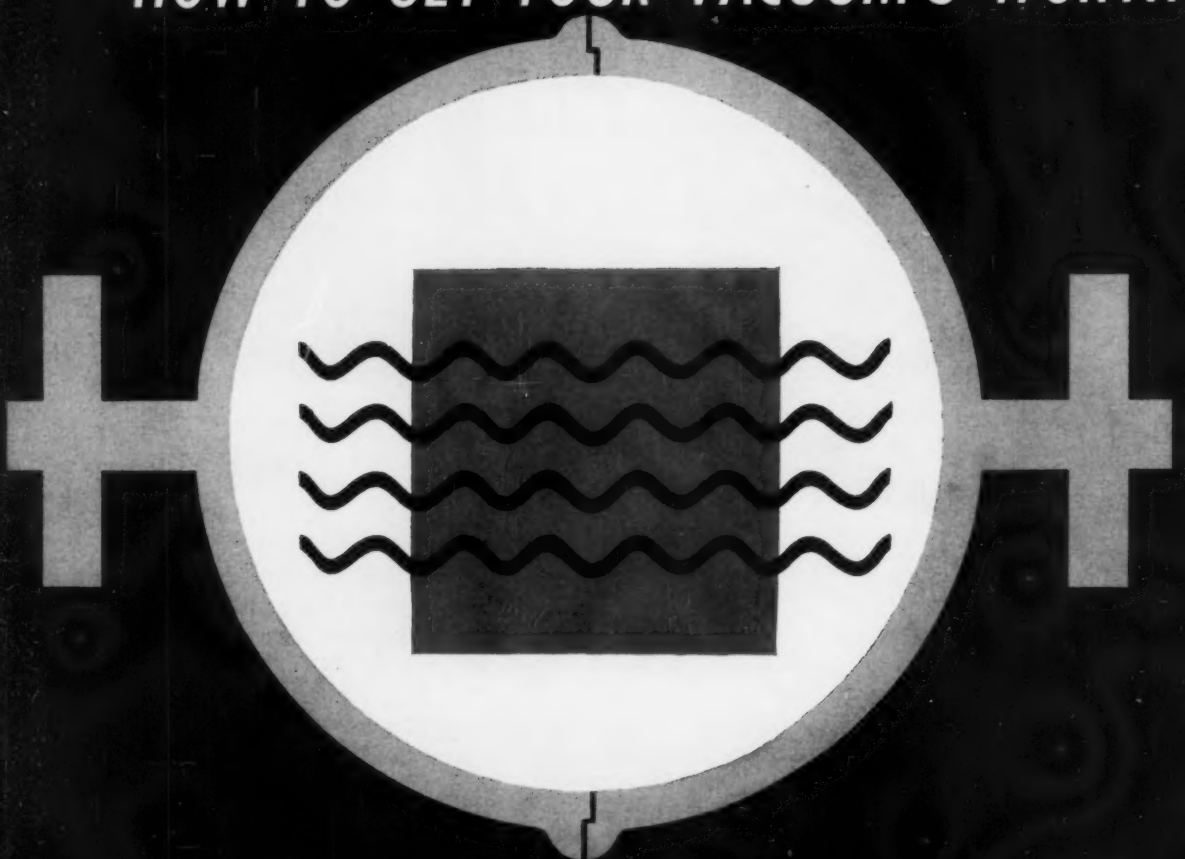

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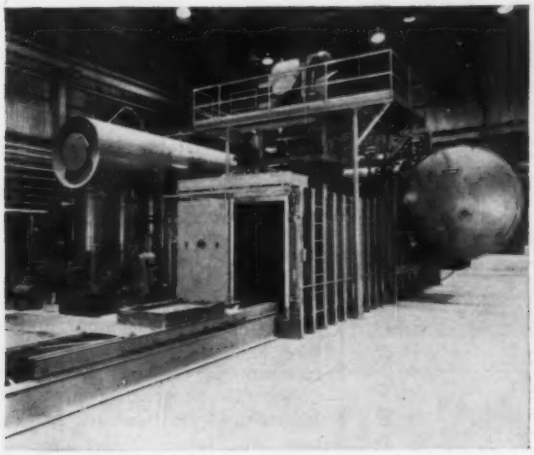
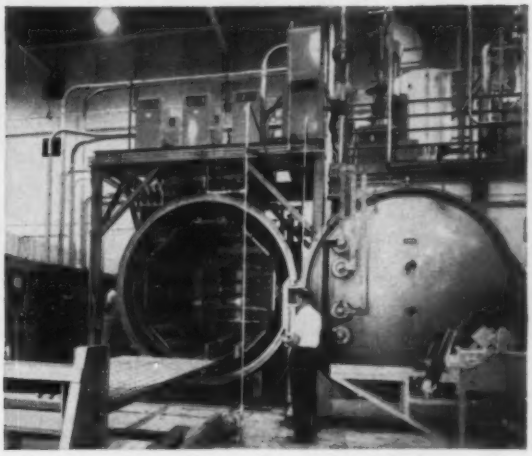
in resistance and induction vacuum furnaces



With a rated capacity of 4,000 pounds, this special-purpose induction vacuum furnace ranks as one of the largest ever built. Designed and built for the Sierra Metals Corporation, the furnace is currently producing nickel- and cobalt-base jet engine alloys. The vacuum pumping system is capable of developing unusually high volumetric capacity at extremely low pressures in the range of one micron.



The Astronautics Division of General Dynamics Corporation puts the world's largest cold-wall vacuum furnace into production. Furnished by Stokes as a complete turnkey installation, the facility is currently being used in production brazing and heat treating of large, stainless steel assemblies.

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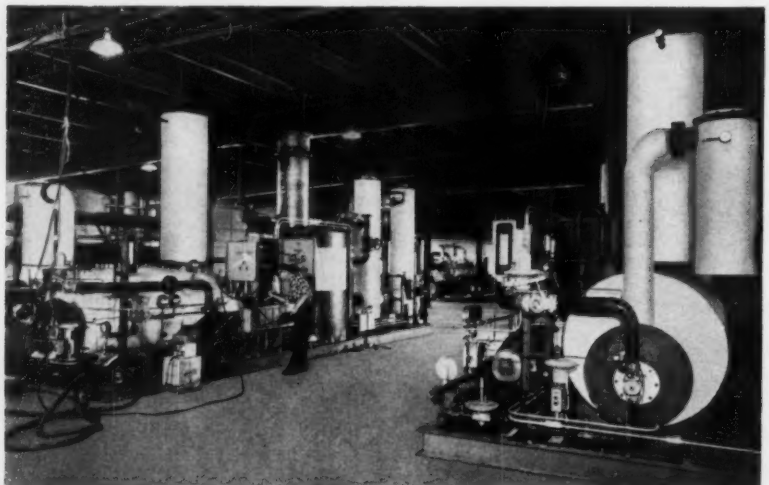

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Circle 1534 on Page 48-B

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Abstracts . . .

were designed to investigate the operation of these processes.

As to results, nickel is inert toward nitrogen, yet it is appreciably weaker in this gas than in vacuum, this reduction being related to an increase in number of intergranular cracks when the material is tested in the gas. Changes in purity of both the metal and the gas affect the results, and are indicative of the mechanism of the process. At sufficiently high temperatures, load-bearing oxide layers form in grain boundary cracks; this may be an important source of "oxidation strengthening".

Effects of Elastic Strain and Environment on the Surface Free Energy of Solid Copper

by S. Floreen, D. V. Ragone and E. E. Hucke

A relationship has been developed to show that the average surface free energy and grain-boundary free energy change with uniaxial elastic strain. In the work reported here, the slopes of stress-strain curves in the elastic region have been measured for copper specimens of different sizes and grain diameters in various environments.

Physical Metallurgy of Refractory Metals — I

Tuesday, October 24 – 9:00 a.m.

Dislocation Substructure in Tantalum and Tungsten

by S. Weissmann and Y. Nakayama

In observing the development of a dislocation substructure in tantalum and tungsten by transmission electron microscopy, the authors noted that progressive deformation led to the formation of a cell structure, and, subsequently, a substructure. First, the cell structure was formed by dislocation entanglements (in which cross-slip played an important role). Then, entangled dislocations constituting the cell wall interacted with entangled dislocations located within the cell to form the substructure. Annealing commercial tungsten above 2500° C. (4530° F.) and subsequent quenching caused the impurities (in atomic form) to segregate on grain boundaries and dislocation networks.

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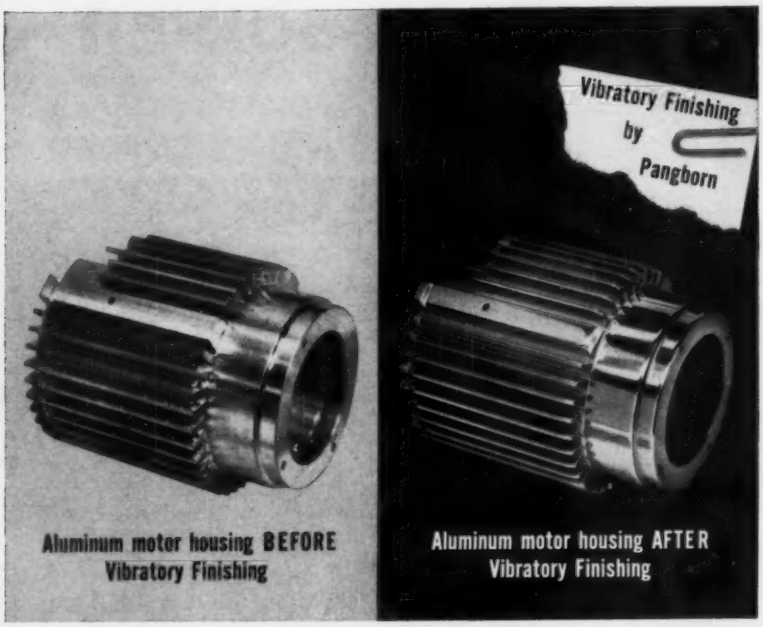
Circle 1535 on Page 48-B

Abstracts . . .

Substructure and Mechanical Properties of Refractory Metals

By Steven Allen, E. M. Passmore and B. S. Lement

The authors are studying the effect of variations in substructure of tungsten, tantalum, molybdenum, and columbium on mechanical properties such as the ductile-brittle transition temperature. The substructure is being measured quantitatively by light and electron metallography and by measuring the broadening of x-ray diffraction lines. Through use of the Warren-Averbach technique, the latter are being analyzed for strain and particle size contribution to line broadening.



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Circle 1536 on Page 48.B

Flow Characteristics of Zone-Refined Molybdenum Over the Temperature Range 4.2° K. to 373° K.

by J. Van den Sype, A. Lawley and R. Maddin

For this work, molybdenum rods were purified by varying numbers of passes, the electron-beam floating zone technique being employed for the operations. Specimens (in the form of single crystals, or coarse-grained material) were pulled to fracture at temperatures between 4.2° K. and 373° K. (−450 to 100° F.). In addition, the authors determined the reversible flow stresses.

Results showed that pure molybdenum behaved in a ductile manner in tension down to 4.2° K. (−450° F.) with a uniform strain of about 5% at this lower temperature. The curve for reversible flow stress versus temperature for material given six zone passes was significantly lower than that for one-zone-pass material, while the latter curve lay below that reported for arc-cast or sintered material. The data are analyzed in the light of the conflicting theories concerning the temperature dependence of yield and flow stresses in body-centered metals.

Flow and Fracture of High-Purity Tantalum-Tungsten Alloys in the Ductile-Brittle Transition Region

by D. P. Ferriss, R. M. Rose and J. Wulff

In this investigation, the authors grew single crystals of tantalum, tungsten and their alloys (by electron-beam zone melting), and tested them in tension between 77 and 373° K. (−320 and 100° F.). The addition of 20% tantalum raised the ductile-brittle transition of tungsten to room temperature. Tantalum-base alloys with 31% tungsten showed a transition at room temperature.

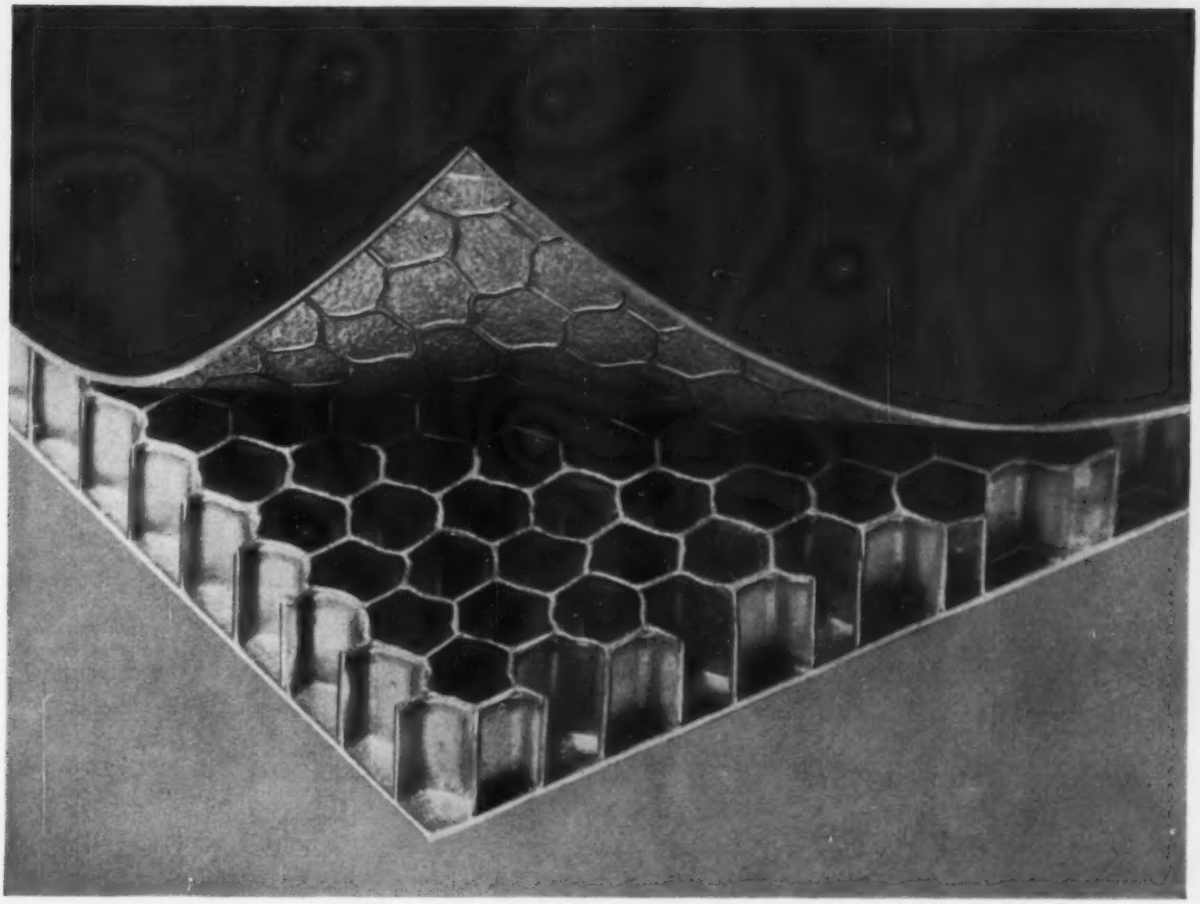
The onset of brittle fracture in tantalum-base alloys was associated with the higher yield and flow stresses required by solid-solution hardening. In high-tungsten alloys, the delineation between ductile and brittle behavior was less clearly established, although the transition temperature was raised by increasing the tantalum concentration.

Notch Sensitivity of Refractory Metals

by A. G. Imgram, F. C. Holden, H. R. Ogden and R. I. Jaffee

Tensile and notch tensile properties of molybdenum, tungsten, co-

Metallurgical Memo from General Electric



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Circle 1537 on Page 48-B

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Circle 1538 on Page 48-B

Abstracts . . .

lumbium, and tantalum and one alloy (Mo-0.5Ti) were investigated. All the materials were evaluated in bar form, the molybdenum and Mo-0.5Ti also being studied in sheet form. For each material, the authors rated notch sensitivities on the basis of several criteria, including the notch-unnotch strength ratio, ductility transition, and fracture transitions.

Effects of Dispersions on the Recrystallization and Ductile-Brittle Transition Behavior of Tungsten

by R. I. Jaffee, B. C. Allen and D. J. Maykuth

Sintered tungsten-base alloys with up to 10 vol. % of finely dispersed materials (oxides, nitrides, and so forth) may be fabricated to strip by conventional hot working procedures. However, the characteristics of the powders must be considered. For instance, ThO_2, ZrO_2, Al_2O_3, and UO_2 are stable, while SiO_2 and MgO are volatilized during vacuum sintering. On the other hand, TiN, ZrN, HfN, TaN, HfC, TaC, and Ta_2C are not stable; nitrogen, carbon, and titanium evaporated when the materials were vacuum sintered, leaving the residual metallic elements. Though residual tantalum and hafnium are detrimental to fabricability, zirconium is not. Primary recrystallization temperatures are raised as much as 200° C. (360° F.) by $ThO_2 + Na_2O$ dispersion, ZrO_2, and residual zirconium or tantalum. Furthermore, the $ThO_2 + Na_2O$ dispersion retards secondary recrystallization up to over 2700° C. (4900° F.), and the ductile-brittle transition is lowered as much as 90° C. (160° F.) by dispersions, with $ThO_2 + Na_2O$ being most effective.

Yield and Fracture in Polycrystalline Tantalum

by M. A. Adams

The author has made tensile tests on specimens of commercial tantalum of different grain sizes, and employed the variation of yield stress with grain sizes to assess the effects of temperature and strain rate. The high resistance on tantalum to brittleness has been confirmed, all of the specimens showing pronounced necking and fractures, which were predominantly fibrous. However, on the fracture surfaces of the coarser-grained specimens tested

WELCOME TO DETROIT

We at the Ford Scientific Laboratory take great pleasure in welcoming you to the 1961 Detroit Metal Show and Metal Congress. We think you will like the bright new look of Detroit's skyline and the facilities of Cobo Hall. This year's meeting in Detroit holds particular significance to us, for it provides a fitting climax to the 10th anniversary celebration of the Ford Scientific Laboratory.

During this 10-year period, we have expanded from a small nucleus of people to nearly 300 persons—and we are still growing. Although this is a small fraction of the 10,000 technical people who make up the Ford Research and Engineering Center, our group is responsible for maintaining a strong science foundation for the present and future technology of the Company.

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Circle 1540 on Page 48-B

Abstracts . . .

at −196° C. (−320° F.), some cleavage facets were observed. Little or no twinning was observed in the tests, probably because the material was not very pure.

Working of Cast Structures

Tuesday, October 24 – 2:00 p.m.

Evaluation of Concast Bloom Sections for Seamless Tube Production

by H. B. Emerick

A trial quantity of square bloom sections made by continuous casting were processed into seamless N-80 casing. The material was examined after rolling to rounds and after piercing, particular attention being paid to the effects of casting defects on product defects. In addition, the properties of the final pipe were compared with those of pipe made from conventional ingots.

Effects of Forging and Rolling on Cast Steels

by Cyril Wells

The paper concerns extensive work on steels containing 0.30 to 0.45% C and 1.5 to 4.5% total alloy content. It discusses the relation between ingot size and reduction of billet cross-sectional area to physical properties, and also includes the effect of segregation and nonmetallic inclusions.

The Role of High Strain Rates and Temperature on the Deformation and Fracture Characteristics of Iron-Carbon Alloys

by Walter Lawson, T. B. King, and N. J. Grant

This report covers a study of fracture ductility of cast, iron-carbon alloys (0.01 to 1.35 wt.% C) in relation to stress, strain rate and temperature. Stress was varied from 1000 to 1800 psi, strain rate from 0.001 to 100% per sec. and temperature from 1600 to 2200° F. These conditions approach those found in hot working processes.

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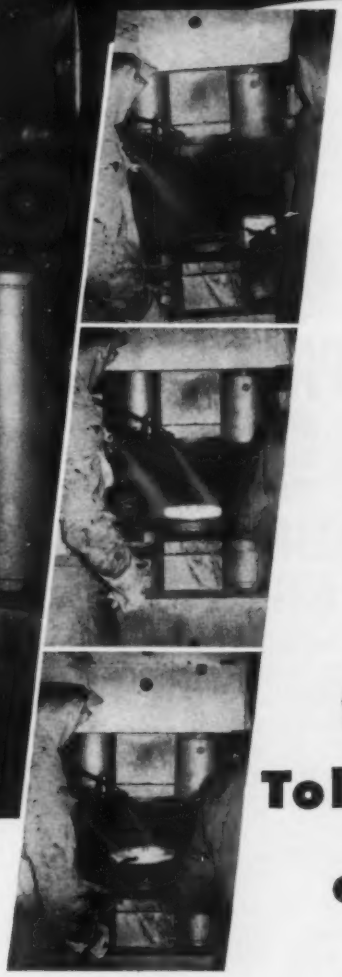

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Circle 1541 on Page 48-B

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Circle 1542 on Page 48-B

Vacuum Techniques in Metallurgy — I

Tuesday, October 24 – 2:00 p.m.

Arc vs. Electron-Beam Melting in High-Vacuum Environments

by R. P. Morgan and T. E. Butler

In recent years, the electron-beam melting technique has attained a dominant position in the field of refractory metal consolidation where a product of exceptional chemical purity is desired. The present paper reviews some of the problems which were encountered in an attempt to achieve similar purities in material processed by the consumable arc method. Factors of arc instability, control of material processing rates, and chemical purity of the ingot product are discussed, with particular reference to the behavior of columbium, tantalum, and tungsten. The authors conclude that, with certain reservations, equivalent product purity can be obtained by either melting technique.

Production Applications of the Electron-Beam Heating Source to the Refractory Metals

by E. F. Baroch and W. A. Aschoff

Electron-beam units are useful for melting, welding, sintering, and annealing refractory metals. This is especially true of melting because the high melting points and relatively low vapor pressures of refractory metals allow vacuum purification. Other factors entering into purification effect are the equilibrium concentrations in the molten state and physical bonding forces.

In welding, current practice involves three distinctly different types of operation. Very narrow beads are being welded in thin, clean, sheet material, electrodes are being fabricated for electron beam or arc melting, and vacuum-melted ingots are being conditioned by sidewall fusion.

The Use of Electron Beams in Vacuum Metallurgical Processes

by J. C. Simons, Jr., and P. L. Raymond

This work reviews the basic technology of electron beams, and describes a vacuum unit which employs three stages of differential pumping. It also presents results for such work as: vacuum evaporating refractory metals to coat metal surfaces; vacuum encapsulating solid materials

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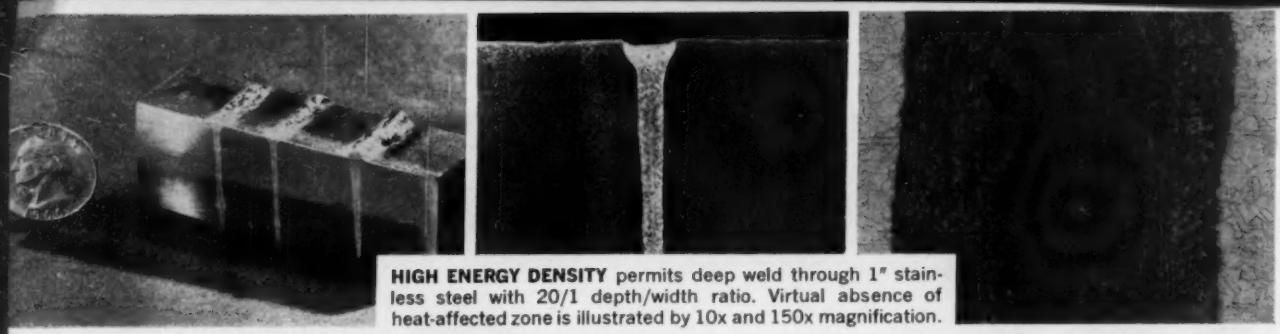

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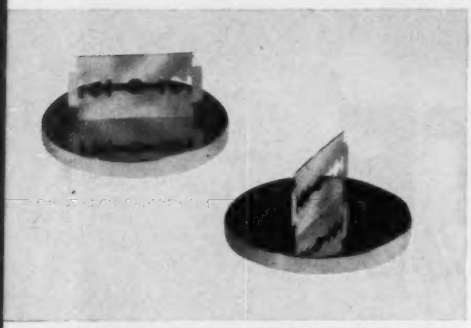

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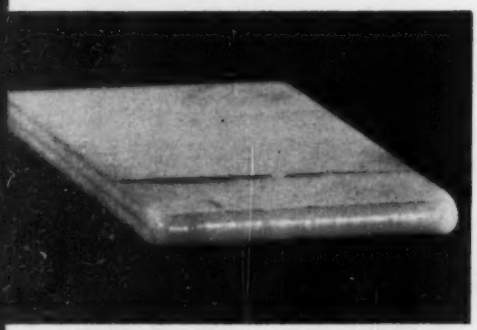

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New Hamilton-Zeiss machine makes precise welds in today's most difficult materials and structures

A new and improved version of the famous Hamilton-Zeiss Electron Beam Welder has been designed, developed and is now being produced by Hamilton Standard.

The machine incorporates larger work chamber, more versatile work-handling equipment, higher power, simplified controls, and many other improvements. It makes deep or microminiature welds with hitherto unattainable precision. It can join dissimilar materials which have widely varying melting points, and weld virtually any refractory metal or exotic material. Hamilton-Zeiss machines are revolutionizing fabrication techniques and innovating new products throughout industry.

KEY ELEMENT OF THE MACHINE is an electron gun, which focuses up to 25 million watts per square inch on the workpiece. Pinpoint concentration means that areas only thousandths of an inch away remain cool and retain their physical properties without distortion. Minimized heat diffusion makes possible highly localized welds within any material or structure.

STRONGEST WELDS POSSIBLE are achieved because the high energy density beam operates in a vacuum; thus, oxidation and contamination problems inherent in other welding processes are eliminated. Moreover, the electron beam, by vaporizing impurities, actually produces welds as strong as the base materials.

WELD CERAMICS, TITANIUM, TANTALUM, MOLYBDENUM,

The new Hamilton-Zeiss electron beam welding machine will be demonstrated at the forthcoming 43rd National Metal Congress and Exposition, Cobo Hall, Detroit—October 23 through 27. Complete information on Hamilton-Zeiss machines for welding or for cutting is available from Hamilton Electrona, Inc., Time-Life Building, New York, New York.

UNITED AIRCRAFT CORPORATION

HAMILTON STANDARD DIVISION

ELECTRON BEAM MACHINES

Circle 1545 on Page 48-B

Cross section of one of eight T welds on an 18-8 stainless steel thin-wall heat exchanger. (Unretouched photo.)

THE MARQUARDT TM-1 A FULLY AUTOMATIC TEST MACHINE

The Marquardt TM-1 Autodynamic Elevated Temperature Test Machine is a fully automatic, servo-controlled universal testing machine which measures and records modulus, yield, ultimate strength, and other mechanical properties of materials.

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- *The TM-1 automatically* runs the test per pre-set conditions.
- *The TM-1 automatically* records the test results in the form of a true stress-strain (psi vs. in/in) curve to failure.
- *The TM-1 automatically* reproduces the identical test conditions on additional specimens for reliable comparisons.
- *The TM-1 automatically* heats (and controls the temperature of) the test specimen.

Tests can be run automatically under rapid heating and loading or straining conditions at temperatures from −300°F to +5,000°F; with true gage length strain control from .002 in/in/min to 45 in/in/min for 1 in. gage lengths; from 50 gm. to 50,000 lb. in tension or compression. Load and strain control include uniform rate, cyclic, or complex programs.

Now in production and designed to meet today's most exacting materials testing requirements, the TM-1 is only one of the testing tools in Marquardt's product line which includes other universal testing machines, programmers, power controllers, extensometers, and related equipment.

For details write: Director-Marketing, 16555 Saticoy Street, Van Nuys, California
Sales representatives' inquiries invited.

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TM-1 CONTROL CONSOLE

TM-1 50,000 LB TEST BED

Circle 1546 on Page 48-B

Abstracts . . .

to alter their effective properties; and vacuum melting of refractory metals for laboratory and commercial programs.

Purification Techniques for Arc Melting Tantalum and Tantalum-Base Alloys
by M. L. Torti and C. A. Hornell

A slow melting rate is an important condition for achieving maximum purification, according to this paper. For this work, two series of ingots were cast, one with a retractable mold-base, the other, with a conventional fixed mold-base. The former group was much purer and more homogeneous. The author also discusses melting behavior and ingot purification of various alloy compositions.

Furnace Reactions With Gases Which Affect the Quality of Vacuum Induction-Melted Uranium
by R. W. Endebrock and E. L. Foster

To a considerable extent, the soundness and purity of uranium fuel slugs is dependent upon process variations in melting and casting. During vacuum melting, interaction of air and water with both uranium and the graphite container components is of particular concern; oxygen, nitrogen, and especially CO play an important part in final metal purity. While some of these gases can be instrumental in helping to form protective drosses, high CO partial pressures can produce higher carbon-oxygen levels in uranium than would result from simple metal-gas reactions. Water is particularly troublesome in that it can react with carbon to produce large quantities of CO.

The Production of Pure Molybdenum and Its Alloys by Floating Zone Melting
by J. A. Belk

High-purity molybdenum has been produced by the electron-bombardment floating zone method of melting. Analysis has shown that the gas content was considerably reduced, and that the reduction of carbon was mainly due to zone refining. Mechanical properties of the purified material (in single crystal and polycrystalline form) are given as are methods for making alloys of the refractory metals.

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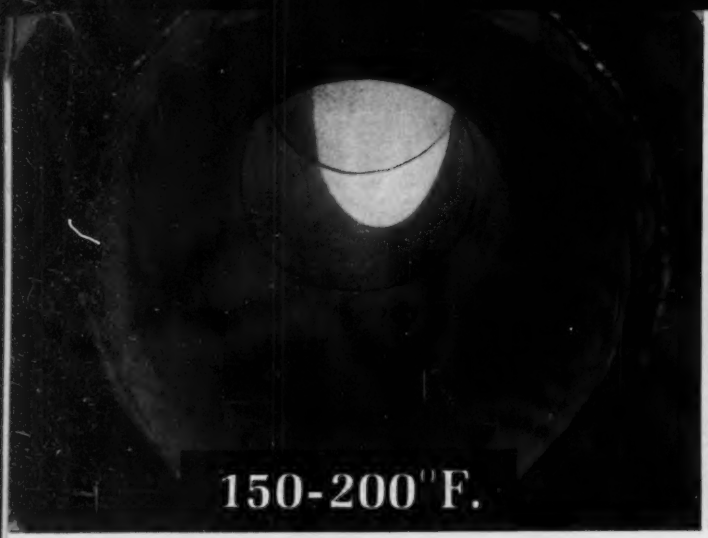
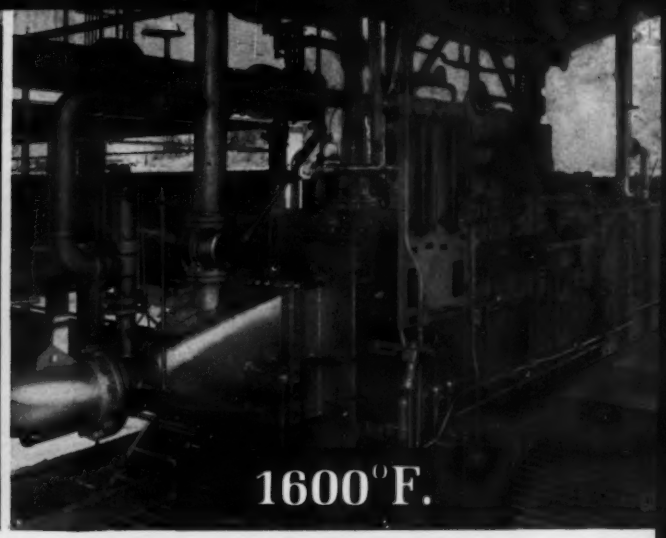
Circle 1547 on Page 48-B





REFRACTORY-LINED PIPE RESISTS ABRASIVE BLAST

This silicon-carbide-lined elbow in air conveying system shows no pitting or other wear after 2½ years. Rubber liners previously used were cut through in less than six months by finely divided cement and asbestos particles in the hot air stream. Exceptional wear resistance of Carborundum's silicon carbide refractories makes them ideal for use wherever severe abrasion is encountered, as in dust collectors, blast furnace down-comers, tees and ells in pipe lines.

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Report from Carborundum:

How specialized refractories excel

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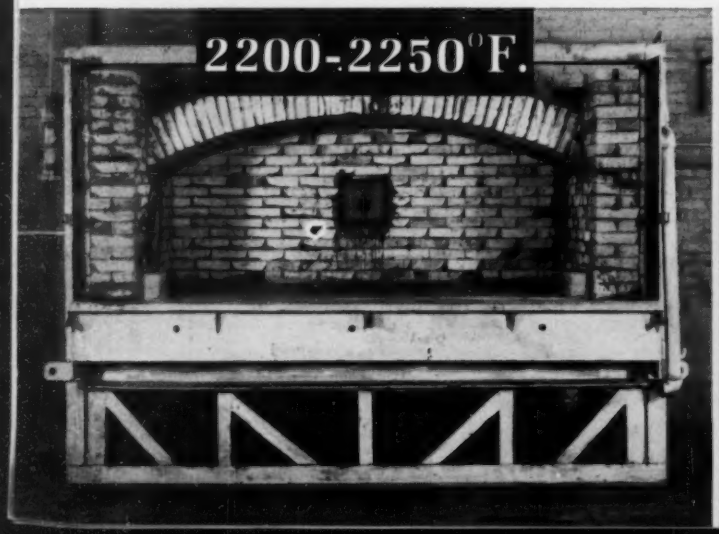
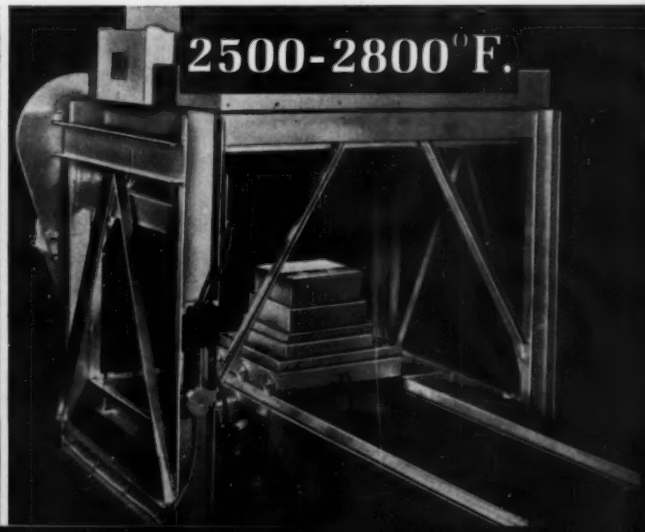
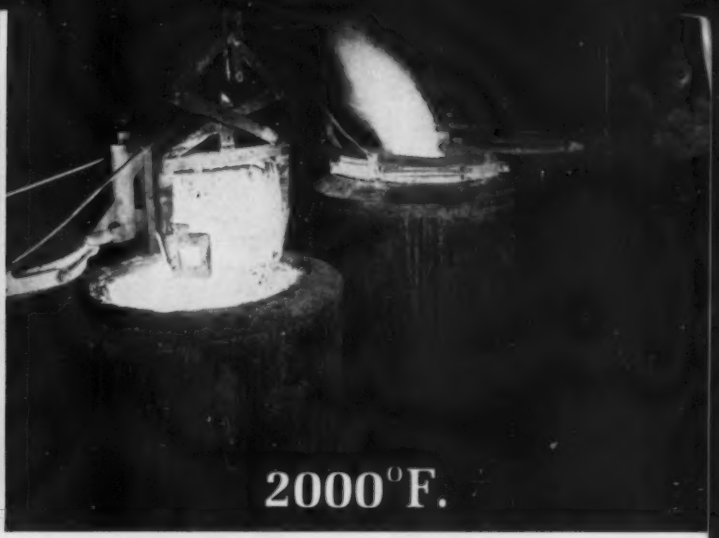
By changing from a firebrick lining to ALFRAX® BI "bubble brick," heating cycle of this slot-type forge furnace dropped from 45 minutes to 30 minutes. This refractory offers high temperature resistance, thermal insulation and load-carrying ability. It is installed in the front, side, and back walls and arch. Silicon carbide brick are used in the floor. Furnace is oil-fired, operates five days a week without shutdown. Materials give 12-18 months service.

REFRACTORY TILE TAKES HEAT SHOCK

Powdered metal parts are raised into this sintering furnace on an "elevator." The parts are placed on a CARBOFRAX® tile on top of the lift. The tile fills the need for high resistance to thermal shock and provides a hard, dense surface. Chamber is lined with ALFRAX® BI aluminum oxide brick, used for low heat capacity, high refractoriness and good thermal insulating value.







SKID RAILS CARRY TONNAGE LOADS WITH MINIMUM WEAR

After one year, these CARBOFRAX® silicon carbide skid rails still looked good as new, though they had carried 16,500 tons of forging billets. Four months later during a shutdown period the total wear was measured as 1/16". Compare this record with the two-weeks service obtained from a rammed chrome hearth. Each replacement required furnace shutdown which, in turn, cut output. Temperature rise through pusher-type furnace is 1400°F.

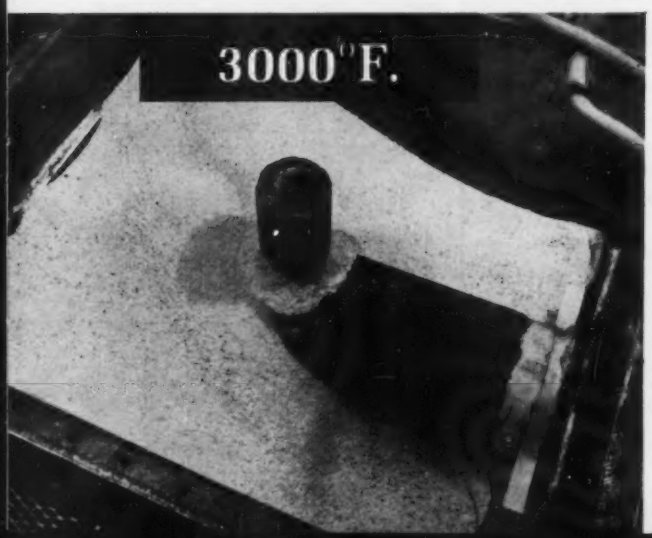
CRUCIBLE LINING FOR Al-Cu ALLOYS HAS LONG LIFE

Each of these crucible furnaces is equipped with a CARBOFRAX® block-type lining. The individual silicon carbide shapes are tongue-and-grooved for strength and stability and are easily installed. Long life of the blocks eliminates frequent patching and permits steady, reliable operation. Clinkers do not form, so that heat radiates uniformly from linings to crucible. The coke-fired furnaces are used to melt high-quality aluminum bronze.

in low to high temperature jobs

THIN-WALLED MUFFLE IS RUGGED, STABLE

This furnace operates up to 3000°F in a hydrogen or cracked ammonia atmosphere. Heat source is a moly ribbon wrapped around an ALFRAX® PK muffle and then coated with insulating cement. Even with its thin walls, power requirements are not excessive. The aluminum oxide muffle is rugged, dimensionally accurate and has long life. Fused alumina "bubbles" piled around muffle are used to insulate the furnace.



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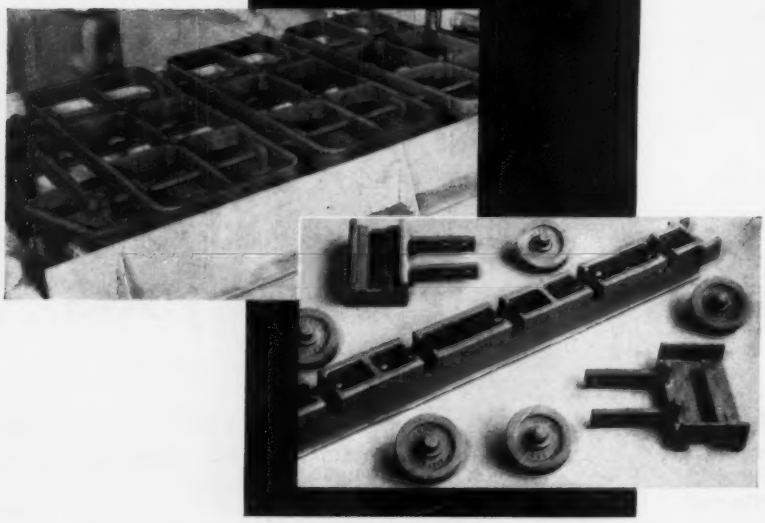
CARBORUNDUM®

Circle 1548 on Page 48-B

HOM CASTINGS

. . . to withstand temperatures in the 2100-2200°F range



The castings shown are for high temperature heat-treating furnaces. They are cast of a special HOM alloy, developed by Duraloy Metallurgists to meet the increasingly higher temperatures now confronting the metal working industries.

HOM is an alloy that retains considerable strength over a broad working area at 2200°F. It can be used for limited applications at 2300°F.

Duraloy Metallurgists—as exemplified by this HOM development—are always on the alert to broaden their service to industry. They have the knowledge, experience and equipment to make good high alloy castings for your requirements whether static, centrifugal or shell-molded. Bulletin G-261 gives full details.

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Physical Metallurgy of Refractory Metals — II

Tuesday, October 24—2:00 p.m.

The Effect of Purity on the Strength of High-Purity Tungsten at Elevated Temperatures

by J. L. Orehotsky

This report concerns the effect of purification on the high-temperature strength of tungsten. Undoped tungsten rods (before and after zone purification) were drawn to wire; these wires, along with doped tungsten wire, were used for the evaluation. The wires were recrystallized to the same equiaxed grain size, and then tested for stress rupture and tensile strength between 800 and 1700° C. (1470 and 3100° F.). At the higher testing temperatures, strength properties varied with purity, the purest wire having the lowest strength.

The high-temperature strength characteristics of the as-drawn (cold worked) wires were also evaluated. At elevated temperatures, the strengths of the cold worked wires were excellent provided recrystallization did not occur during testing.

The Effects of Interstitials on the Properties of Cb-Rich Alloys in the Cb-W-Zr System

by J. W. Clark

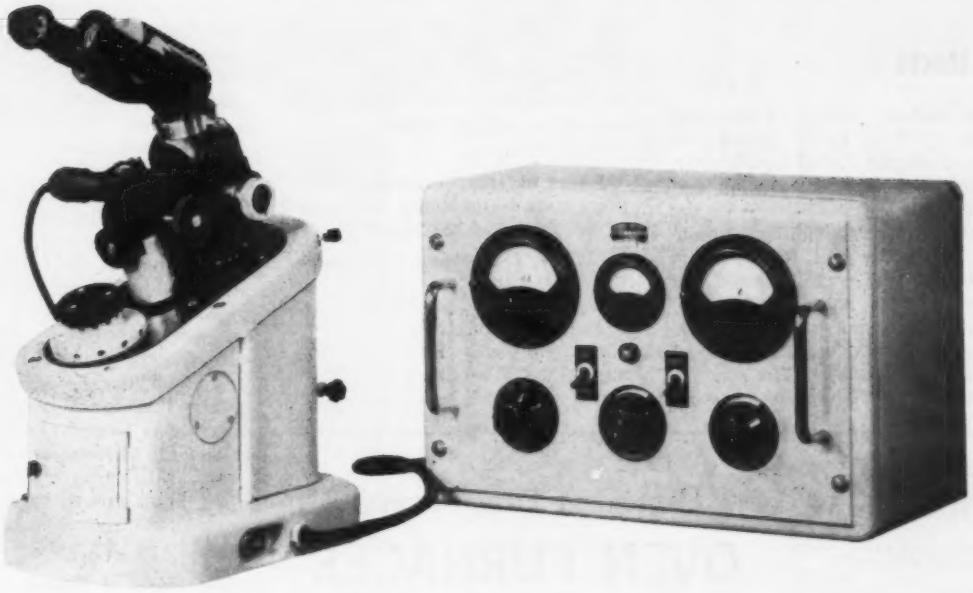
This paper, which concerns the effects of interstitial elements on the mechanical properties of wrought alloys in the Cb-W-Zr system, places emphasis upon creep-rupture behavior in the 1100 to 1200° C. (2000 to 2200° F.) range, ductility at room temperature, and the correlation of these properties with microstructure.

At zirconium levels of 0.5 to 2.0%, the optimum combination of creep resistance and low-temperature ductility is obtained with Zr/C atomic ratios near unity. At these concentrations, a fine, uniformly distributed dispersion is observed. In a typical alloy, the 100-hr. rupture at 1093° C. is greater than 40,000 psi., elongations of over 10% being retained in room-temperature tensile tests.

Strengthening of Mo-Ti-Zr Alloys With Carbon and Boron

by M. Semchyshen and R. Q. Barr

Work with molybdenum alloys containing titanium or zirconium (or both) indicated that the strength properties were sensitive to the re-



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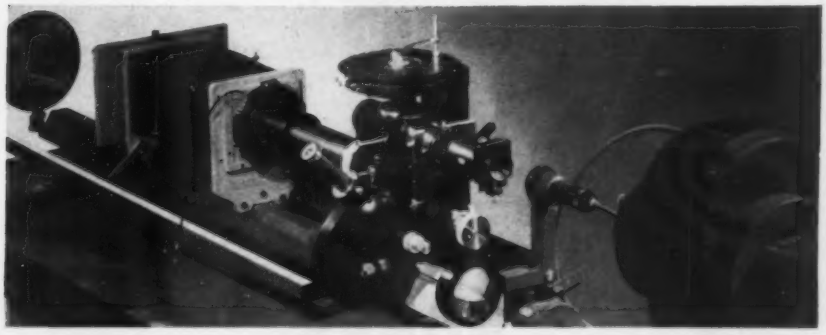

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Circle 1550 on Page 48-E

Abstracts . . .

sidual carbon content. Depending on the C/Ti (or C/Zr) ratio in the alloys, strengths varied significantly. In both systems, the optimum carbon content was about 10% of the alloying element, a similar relationship being observed for alloys in which carbon was replaced by boron. In the latter group, however, strength properties were generally lower than those for carbon-containing materials. The strength dependence of molybdenum-base alloys containing titanium or zirconium (or both) with carbon is attributed to the locking of dislocation movement by the critical dispersion of the carbide phases.

Effect of Heat Treatment and Precipitation Hardening on Strength Properties of Mo-Base Alloys

by W. H. Chang and L. P. Jahnke

In a previous investigation, the hardening process in a molybdenum alloy (containing 1% Ti, 0.1% Zr and 0.14% C) was shown to be associated with the precipitation of TiC accompanied by simultaneous dissolution of pre-existing Mo_2C upon aging. This paper discusses the effect of heat treatment on the tensile and rupture strength of this alloy in both worked and nonworked conditions.

In the worked condition, it is greatly strengthened by prior high-temperature annealing, or annealing and aging. In the nonworked condition, low-temperature strength is increased by aging, whereas high-temperature strength is enhanced by annealing alone to the extent that it is equal to the strength of the worked condition. Experimental observations have generally been correlated to the state of carbide dispersion as affected by heat treatment, and the interplay between strain and precipitation hardening is discussed.

The Effect of Yttrium and Selected Rare Earth Additions on the Removal of Interstitials From Tungsten and Molybdenum

by D. T. Klodt and J. F. Nachman

Ingots of molybdenum and tungsten alloys were prepared by melting the base metals with yttrium or selected rare-earth metals. Grain refinement, reductions in as-cast hardness, and increased ingot soundness were noted in most of the molybdenum alloys, but were not observed in the tungsten alloys. The efficiency of the removal of interstitial elements by the yttrium or rare-earth additions was evaluated by torsion ductility and ductile-to-brittle transition tests.

The Physical and Mechanical Properties of a Chromium-Base Alloy

by R. E. Cairns, Jr., and N. J. Grant

In this study of a chromium alloy containing 1% Cb and 0.25% Y, the authors investigated the transition temperature (in the recrystallized condition and after various amounts of prestrain), the dynamic modulus of elasticity (over the 70 to 2000° F. range), the high-temperature strength (at 1500, 1800 and 2000° F. in the recrystallized condition, and at 1500 and 1800° F. in the prestrained condition), and the oxidation resistance.

Electron Metallographic Techniques for Studying Tungsten Wires and Powders

by Charles F. Tufts

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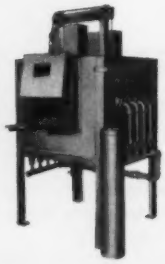
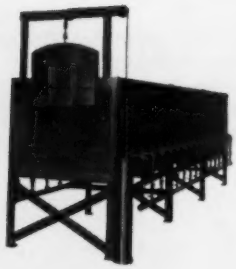


Melting Furnaces



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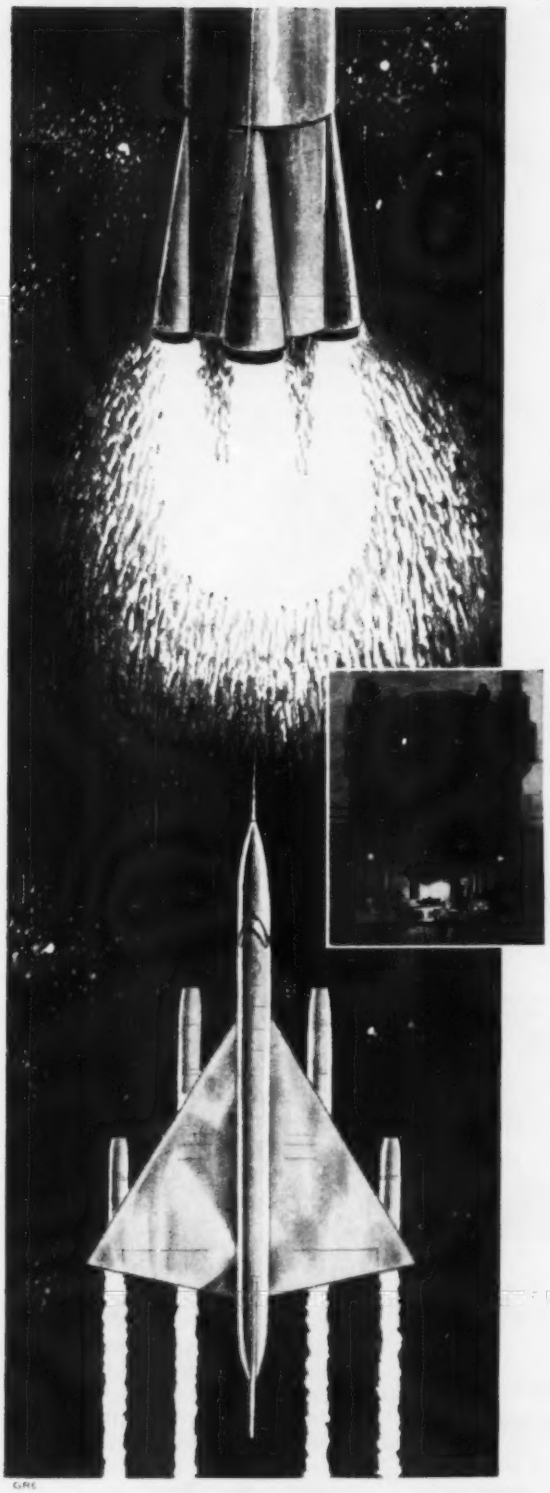

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Circle 1552 on Page 48-8

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Circle 1553 on Page 48-B

Abstracts . . .

needed to observe substructures adequately; this makes electron optical methods obligatory. In addition, replication methods of electron metallography allow the observer to determine the size and habit for aggregates and single particles contained in powder specimens. This report discusses and illustrates recent advances in the carbon replica method for the electron metallography of tungsten wires and powders, and gives experimental details for specimen preparation using platinum preshadowing in conjunction with parlodion-carbon replication.

Nuclear Fuel Reprocessing — I

Wednesday, October 25 — 9:00 a.m.

Phase Relationships in Plutonium Halide Binary Fused Salt Systems

by J. A. Leary and K. W. R. Johnson

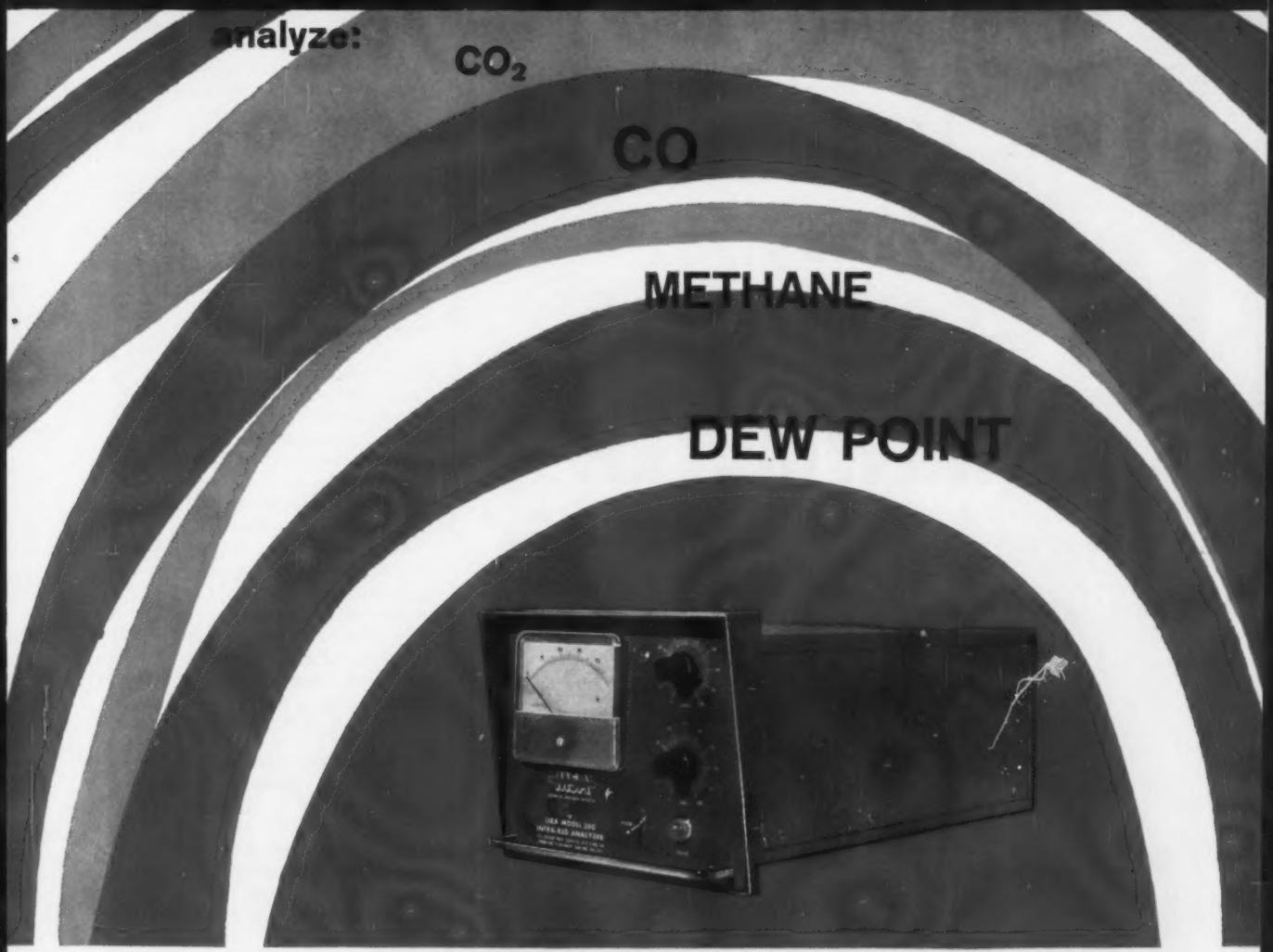
With the recent application of fused salt technology to plutonium processing, interest has been stimulated in phase relationships of plutonium-salt systems. As a result, binary phase diagrams for the systems $PuCl_3$ plus LiCl, NaCl, KCl, RbCl, CsCl, $MgCl_2$, $CaCl_2$, $SrCl_2$, and $BaCl_2$ have been determined over the complete composition range. In general, the larger the ionic radius of the alkali and alkaline earth cation, the greater the tendency to form compounds with $PuCl_3$. Thus, systems containing LiCl, NaCl, $MgCl_2$ or $CaCl_2$ are represented by a simple phase with no compound formation. All other systems contain at least one compound.

Processing of Uranium Dioxide Fuel by the Salt Cycle Process

by M. T. Walling, Jr.

This report discusses the development of the salt cycle process for uranium dioxide fuels, a key feature of which is the production of fuel-grade UO_2 by cathodic reduction of uranyl chloride dissolved in molten chloride salts. Results are presented on the closure of the fuel cycle through this process, and on studies of the electroyltic reduction of uranyl ion to UO_2. Also covered are methods for incorporating plutonium dioxide (or thorium dioxide) in the deposited UO_2, and producing large crystals of UO_2.

furnace atmosphere control?



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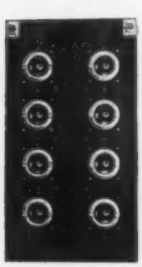

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Circle 1554 on Page 48-B

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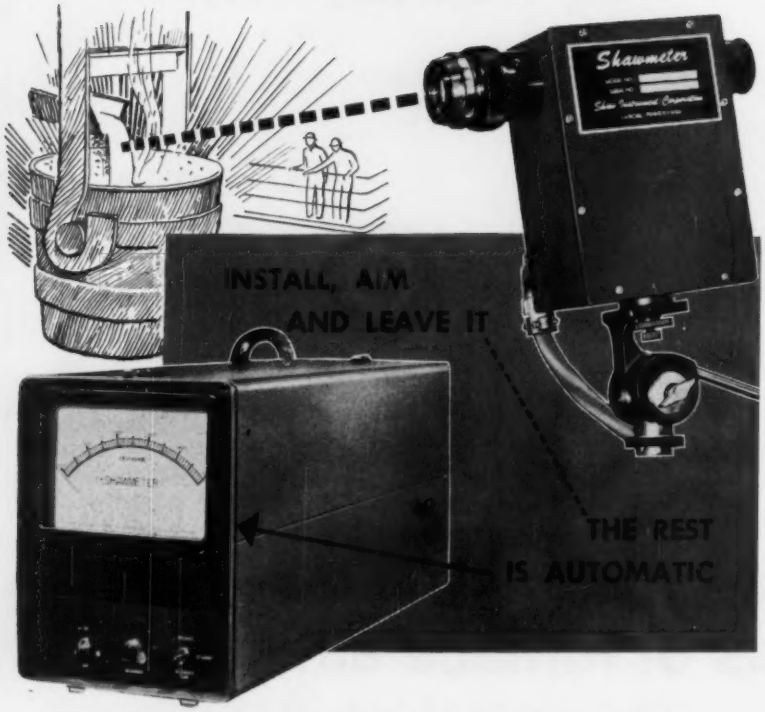

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Circle 1553 on Page 48-B

Abstracts . . .

Fused Salt Oxidation-Reduction Process for Plutonium Fuel Recycle

by James G. Reavis

The author has evaluated a chloride conversion cycle as a pyrometallurgical process for plutonium-rich metallic fuel. In this technique, the impure fuel is reacted with zinc chloride in sodium chloride solution between 500 and 860° C. (930 and 1580° F.). Three separation phases are evolved, two liquid and one gas. Plutonium and electropositive fission products are converted to the respective chlorides which are soluble in the molten salt phase. Meanwhile, the phase of liquid zinc dissolves the less electropositive elements (such as molybdenum and ruthenium), and volatile elements and chlorides (zirconium chloride, for instance) separate into the gas phase.

After separating the two liquid phases (by filtration), plutonium chloride in the salt phase is reduced to recover the plutonium. The ternary plutonium-cerium-cobalt is a liquid metal fuel which can be regenerated directly by reduction with cerium-cobalt alloy.

Recent Developments in the O.R.N.L. Volatility Process

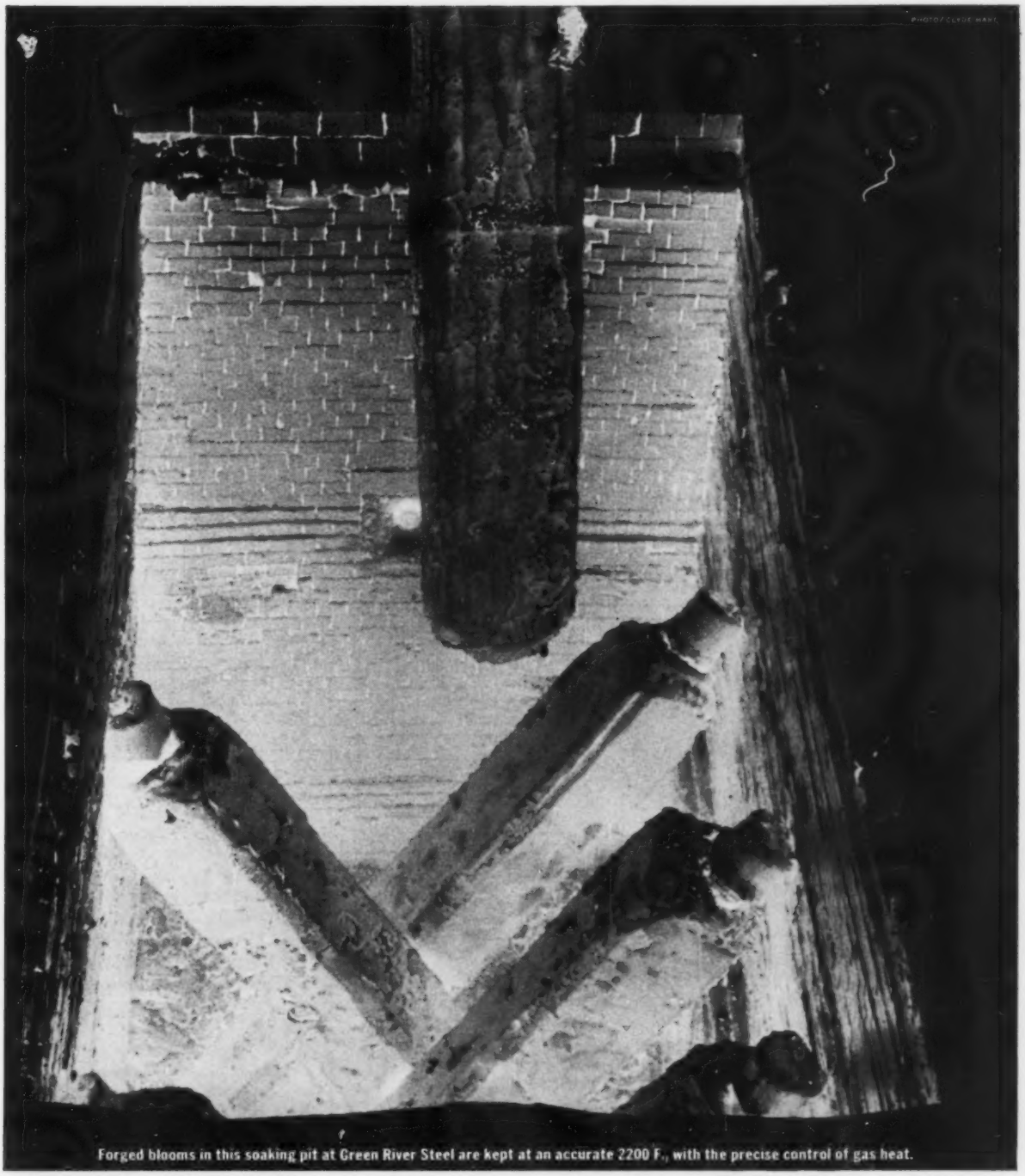
by C. E. Guthrie

In this process, now in the pilot stage, fuel elements of uranium-zirconium alloy are dissolved in a molten fluoride salt which contains hydrofluoric acid. After the uranium is converted to UF_4, the molten salt is transferred to another vessel for reaction with fluorine to recover the uranium as volatile UF_6. The process can also be used to recover uranium from BeO and ZrO_2 fuel types.

Liquid Metal Processing of Fuel From the Second Experimental Breeder Reactor

by R. D. Pierce and Leslie Burris, Jr.

Liquid metal solvents are now under study as a means for processing reactor fuels, the main objectives at present being to reduce fuel cycle costs in the EBR-II unit. A simple process, melt refining, provides for quick recovery and recycle of the bulk of the discharged fuel. A process employing zinc-magnesium solvent combinations is being developed to recover uranium remaining in the refining crucible (as oxide and unpoured metal), and a similar proc-



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Circle 1556 on Page 48-B

ess has been devised for separating plutonium bred in the uranium blanket of the reactor. Fused salts are also being used in combination with liquid metals to enhance heterogeneous reaction rates. Although present applications are specific, the processes are of general utility and can be applied to other fuels.

The Fluidized Bed in Radioactive Waste Disposal

by J. I. Stevens

As a means for disposing of radioactive waste, much work (both in the laboratory and pilot plant) has been done with the fluidized-bed technique. This report presents the results of pilot-plant work on the calcining of wastes from aluminum-type fuels over the 250 to 550° C. (480 to 1020° F.) range with fluidizing velocities from 0.8 to 1.0 ft. per sec. Other variables investigated have included feed composition, designs and operating conditions for pneumatic-atomizing feed nozzles, and return of fine particles to the bed. The author also presents a process flowsheet of the Demonstrational Waste Calcining Facility, and describes the results of the first runs with simulated aluminum waste.

Vacuum Techniques in Metallurgy — II

Wednesday, October 25 – 9:00 a.m.

Zone Purification of Yttrium

by W. C. Necker

This paper describes the equipment, processes and techniques used to maintain and traverse a molten zone through metallic yttrium, and includes a brief discussion of zone refining mechanisms and their influences on process selection. Equipment design, including power source, coil design, vacuum system, and vacuum measurement, are also covered.

Separation of Sulfides by Vacuum Distillation

by G. N. Banks, R. A. Campbell and R. R. Rogers

For this work, the authors investigated the separation (by vacuum distillation) of lead and zinc compounds contained in complex sulfide ore concentrates, studying the effects of temperature, pressure and heating time. According to the results, lead-free residues could be obtained from a lead-zinc-copper-iron concentrate, and also from a zinc concentrate. In both instances, the zinc which remained in the residue could be removed by redistilling at a higher temperature.

The Status of Vacuum Methods of Gas Analysis for Oxygen, Nitrogen and Hydrogen in Metals

by N. A. Gokcen

This paper concerns improvements and limitations in current methods of analysis of oxygen, nitrogen and hydrogen in metals and alloys by the vacuum technique. In discussing the accuracy of results, the author describes methods for preparing highly accurate samples for standards.

Brazing and Heat Treating in Vacuum

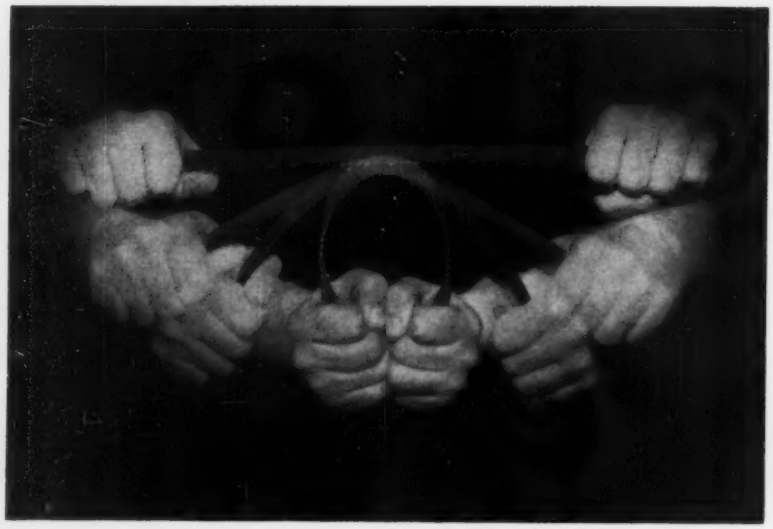
by R. F. Gunow

Two classes of vacuum furnaces have been developed for brazing and heat treating – the "hot-wall" and "cold-wall" types. In conjunction with these, engineers have devised new brazing alloys for vacuum processing. Many complicated parts can now be produced with vacuum brazing techniques, including high-temperature heat exchangers, turbine assemblies, and nuclear fuel elements.

New Developments in Oil Diffusion Pump Design for Vacuum Metallurgy

by M. H. Hablanian

The performances of diffusion pumps have been significantly im-



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Circle 1557 on Page 48-B

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Circle 1559 on Page 48-B

Abstracts . . .

proved in recent years according to this paper, which presents latest developments in pump design. In discussing them, the author considers problems involving design of high vacuum systems for metallurgical processing, and cites specific examples in which such systems are employed.

Nuclear Fuel Reprocessing — II

Wednesday, October 25 – 2:00 p.m.

Thorium Recycle Development

by D. E. Ferguson, E. D. Arnold, O. C. Dean and W. S. Ernst, Jr.

Engineers at Oak Ridge National Laboratory are devising better methods for preparing and fabricating ThO_2 fuels. Because of the activity of the decay products of U^{232} in U^{233} and Th^{228} in thorium from power reactors, new fuel elements must be processed (from recycled fuel) by remote methods. Pure ThO_2 or mixed ThO_2-UO_2 can be prepared by the sol-gel process and loaded into fuel element tubes by vibratory compaction. Eight capsules made by such techniques are now being irradiated in the NRX for future testing.

Scientific Developments Connected to the Eurochemic Reprocessing Project

by R. E. Rometsch

The characteristics of the Eurochemic processing plant reflect many different demands. For example, since the plant is expected to prove the feasibility of multipurpose reprocessing by accepting a wide range of various fuel elements, it must be conceived as a pilot plant. Yet it should also guarantee a certain production capacity and, last but not least, provide economic data with sufficient precision to allow extrapolation to a high-capacity plant. The author also plans to discuss several problems in experimental research.

Reprocessing Fast Reactor Fuels at Dounreay

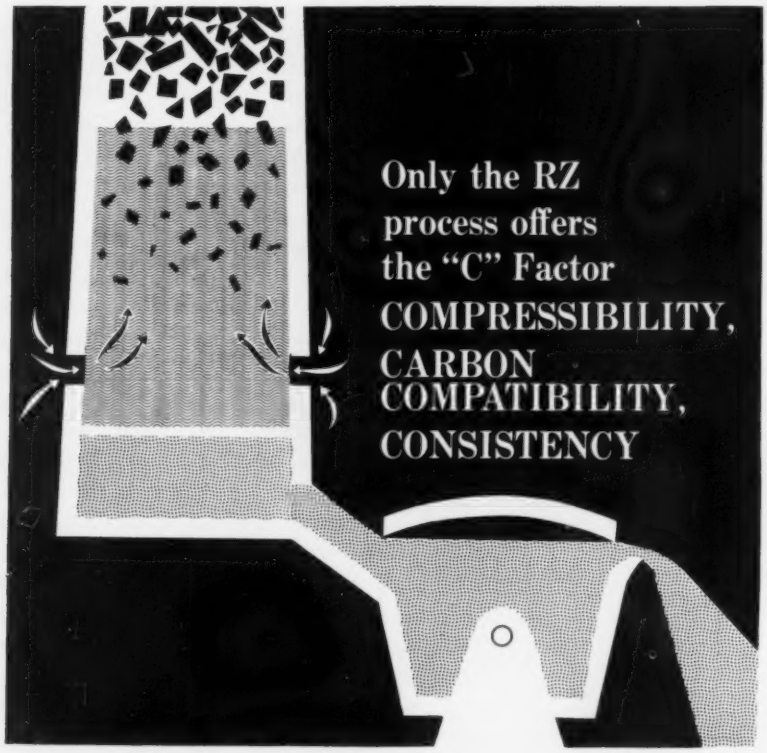
by D. M. Donaldson, K. Hartley, P. Lees and N. Parkinson

In England, engineers are developing a fast breeder reactor system powered by compounds: fuels under consideration include oxides, cermets and carbides. Reprocessing work has been directed towards "head-end" processes for preparing fuel solutions which can be reprocessed by available units, and to a study of problems arising from the processing of fuels containing 15 to 50% Pu. Much processing information is given in this report.

Recent Developments in the Processing of Nuclear Fuels by Ion Exchange

by D. B. James and E. L. Christensen

This report, which reviews ion-exchange processes for thorium, uranium and plutonium, presents a qualitative discussion of the driving forces that produce separations.



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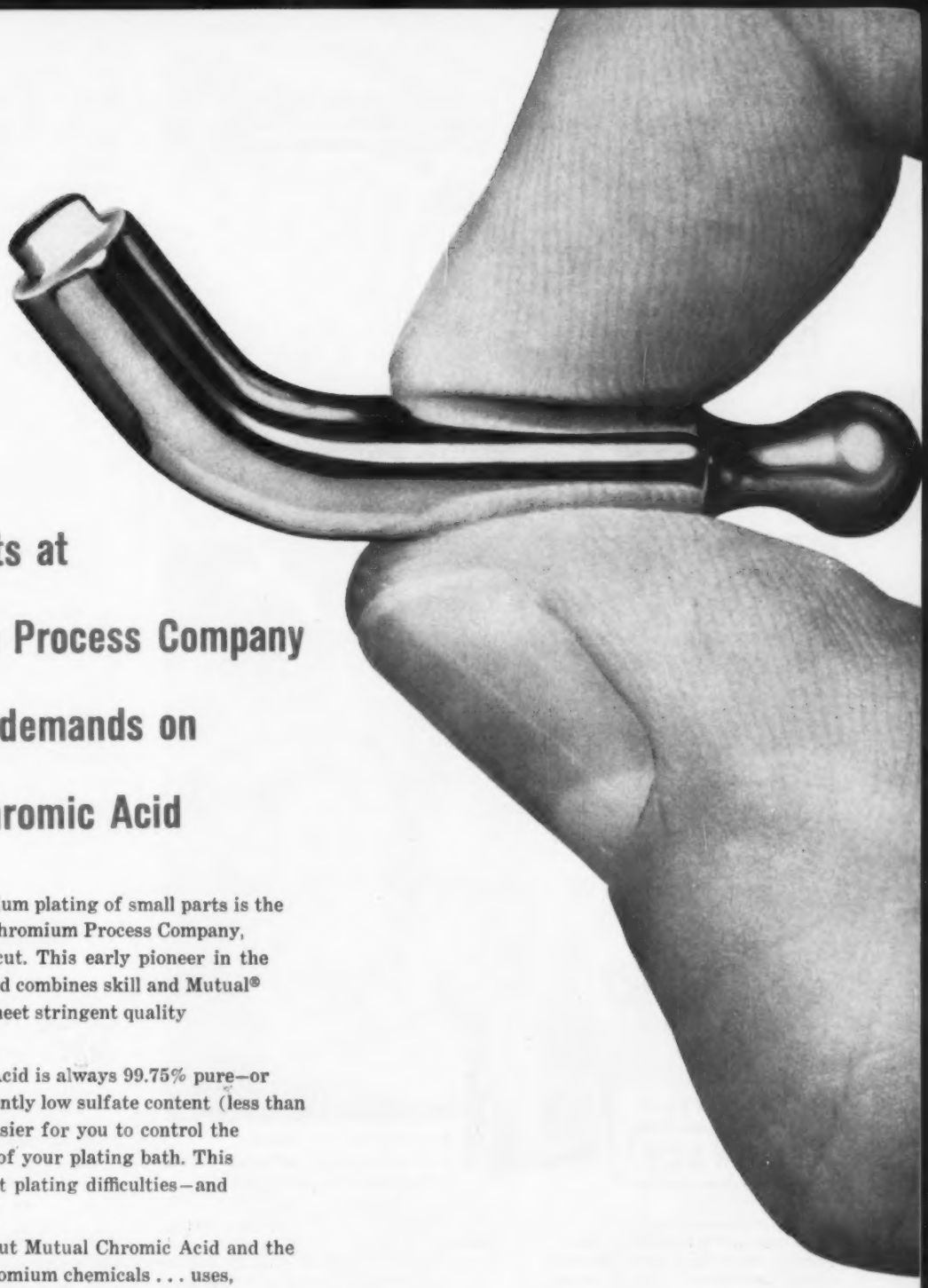

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Circle 1561 on Page 48-8

The Corrosion of Containment Materials by Molten Zinc and Cadmium Alloys

by J. DeKany, H. Lavendel and L. Burris

A corrosion program was undertaken to find materials which would contain liquid zinc, cadmium, magnesium and their combinations. (These systems are encountered in developing processes for recovering uranium and plutonium from spent reactor fuels.) First, all potentially usable materials were screened by the 100-hr. static capsule tests; then, promising materials were subjected to the 1000-hr. dynamic capsule tests, or used in forced or thermal convection loops.

These tests have shown that molten cadmium alloys may be satisfactorily contained in mild steel or nickel-free ferrous alloys under static and dynamic conditions up to at least 550° C. (1020° F.) and probably somewhat higher. At 700° C. (1300° F.), however, these steels are attacked by molten cadmium. For resisting molten zinc up to around 800° C. (1470° F.), only tungsten, tantalum, and molybdenum showed substantial resistance to attack, tungsten being completely inert. Alumina, silicon carbide, silicon nitride, zirconium, Vycor, and graphite were unaffected by zinc at 750° C. (1300° F.) except when magnesium was present. Then, Vycor and silicon nitride were severely corroded.

The Corrosion of Materials of Construction for Multipurpose Head-End Equipment in Proposed Fuel Reprocessing Schemes

by W. E. Clark

The necessity for reprocessing a wide variety of experimental nuclear fuels has created interest in developing multipurpose processing schemes. This paper considers the corrosion problems in multipurpose aqueous head-end processes for stainless steel and zirconium fuel types, comparing them with those in certain combustion and fused salt processes. Corrosion data, presented for competitive aqueous processes, are also compared with those for the fused salt-volatility process, and areas requiring future corrosion work are outlined.

Selected Research Abstracts

Dislocations and Their Interactions

Monday, October 23 – 2:00 p.m.

Fast Moving Edge Dislocations on the (110) Plane in Anisotropic Body-Centered Cubic Crystals

by J. Weertman

The author has obtained the elastic displacement field around a uniformly moving edge dislocation for the situation where the dislocation glides on a (110) plane in a <111> direction in an anisotropic body-centered cubic crystal, and determined a general solution which involves elastic displacements in all three coordinate directions. An equation is given for the Rayleigh wave velocity at which the shear stress on the slip plane of a moving dislocation is zero. Dislocations of like sign moving faster than this velocity attract rather than repel each other.

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Fast Moving Edge Dislocations in Alpha Iron

by J. Cotner and J. Weertman

The authors have calculated the shear stress on the slip plane of an edge dislocation moving uniformly in the alpha iron lattice. They have found that the shear stress approaches zero at the Rayleigh wave velocity, 0.92c, where c is the shear velocity in the <111> direction. In the velocity range between 0.92c and 0.94c (the limiting velocity of dislocation motion), dislocations of like sign attract one another.

On the Nature of Dislocations Which Cause Nonbasal Slip in H.C.P. Metals

by H. S. Rosenbaum and M. L. Kronberg

While cadmium, zinc, and magnesium crystals slip mainly on the basal plane, metals with lower c/a ratios (titanium, zirconium, and beryllium, for example) slip mainly on nonbasal planes. Furthermore, even cadmium, zinc and magnesium crystals can be made to slip on nonbasal planes if they are suitably stressed. This report is concerned with the geometric nature of the dislocations which cause nonbasal slip; a hard sphere model is used to describe the atom movements required to produce slip.

Solution Hardening

by Robert L. Fleischer

Solution hardening is considered for the situation of elastic interaction between a dislocation and a random solid solution. The author proposes that the major elastic interaction of a dislocation with a solute atom occurs because the atom has a shear modulus which differs from that of the matrix, so that individual atoms may be represented by elastic "spots" which are hard or soft. For edge dislocations, this effect is considered comparable to that due to atomic size misfit. In addition, since the modulus effect provides an interaction with the shear portion of the strain field of a dislocation, screw as well as edge dislocation will be opposed. It is also noted that impurity pinning of all dislocations (not merely edge dislocations) will arise from modulus differences; thus yield points are to be expected.

The Formation of Point Defects During Deformation

by H. K. Birnbaum

This paper concerns the generation of point defects during plastic deformation of copper, and their subsequent interaction with dislocations. Within the test temperature range, 77 to 373° K (−320 to 100° F.), two types of point defects (the interstitial and the vacancy, according to analysis) were observed to anneal. Both defects interacted with dislocations to give rise to a small yield effect and an increase in the elastic modulus. Analysis of the aging kinetics indicated that the data were consistent with a model of the point defect annealing in which the defects diffused to dislocation lines and along the dislocations to sinks.

Density and Distribution of Dislocations in Copper Crystals Deformed in Tension

by J. D. Livingston

In single crystals of pure copper deformed in tension, four different tensile axis orientations have been studied. Occasionally, deformation was interrupted to measure dislocation density by etching techniques capable of revealing dislocations.

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The author discusses his observations as related to current theories of deformation and work hardening of face-centered cubic metal crystals.

X-Ray Diffraction Micrographic Observations Dealing With Nature and Origin of Dislocations in "Pure" Zinc Monocrystals Solidified From the Melt

by R. W. Armstrong and J. M. Schultz

Randomly oriented and specially oriented single crystals of zinc have been examined with x-rays to obtain evidence concerning the nature and properties of the initial distribution of dislocations which exist within the solid. This study deals with: *(a)* The characteristics of dense patterns of dislocation lines grown into the crystals, and *(b)* the observation of dislocation rings, spiral loops, and slip dislocations. As for results, though an individual line of the x-ray fine structure may sometimes represent an individual dislocation, in numerous other instances an individual line represents a small group of parallel dislocations. The authors discuss these line observation in detail.

Application of the Berg-Barrett X-Ray Technique to "Seeing" Dislocations in Zinc

by J. M. Schultz and R. W. Armstrong

The authors, in reporting on an x-ray diffraction micrographic study of single crystals of zinc, have associated the fine line structure of the x-ray diffraction spots with the intrinsic character and properties of individual or small groups of parallel dislocations rather than with anomalous x-ray effects, impurity effects, or crystal surface effects. Their reasoning is carefully analyzed in this paper.

Dislocation Mobility in Magnesium

by G. S. Ansell, M. J. Roblin and R. S. Goodrich

The authors report the use of sequential photographs to get stress-velocity measurements for both edge and screw dislocations in magnesium by transmission electron microscopy. To compare these velocities with those measured by the etchpit technique, dislocations ending at a free surface were also studied. Although stationary, these dislocations were heavily bowed indicating that a large surface drag force existed. Thus, according to the authors, it would appear that the stress for dislocation mobility measured by the etch pit technique is consistently higher than the actual stress required for dislocation motion in the bulk material. Observations of "Taylor locking", forest-type intersection, and an edge-screw interaction were also made.

Studies of Dislocation Density and Deformation in Single Crystals of Lead Sulfide as a Function of Stoichiometry

by Wilbur Franklin and J. B. Wagner, Jr.

Some properties of the partially polar semiconductor compound, lead sulfide, were investigated as a function of the deviation from the stoichiometric composition. In undoped and silver-doped single crystals, the authors noted a very small, but reproducible, variation in dislocation density with deviation from stoichiometry. They also investigated the critical stress to initiate glide by pushing a prism of material through cleaved samples having (100) cleavage faces; crystals having

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Circle 1566 on Page 48-B

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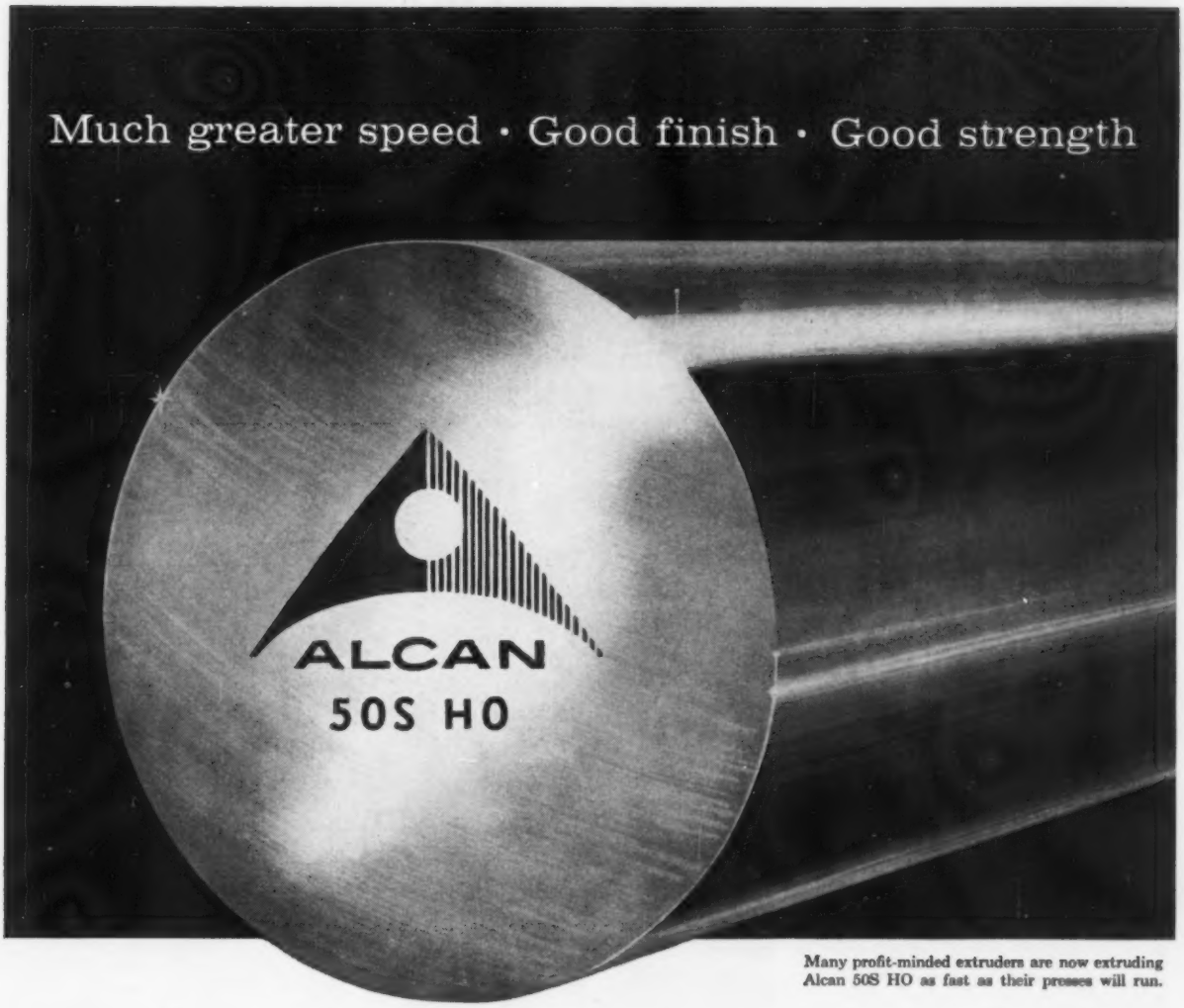

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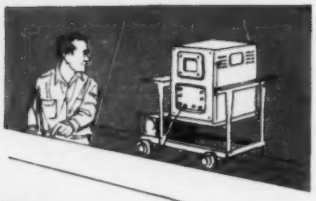

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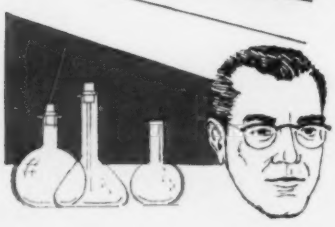

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Circle 1568 on Page 48-B

greater defect concentrations (that is, excess lead or excess sulfur) required greater stress to deform than specimens near the stoichiometric composition.

The Investigation of Fatigue in Metals by Means of Etch Pits at Dislocation Sites

by A. H. King

New chemical etching techniques permit dislocation arrangements and movements to be observed while under an applied stress in single crystals of copper. At appropriate crystal orientations, it appears possible to distinguish between positive and negative edge dislocations. These techniques have also been used to compare dislocation movements during the early stages of fatigue in bending in copper and copper alloys of known stacking fault energy.

Work Hardening and Strengthening Mechanics

Wednesday, October 25 — 9:00 a.m.

Work Hardening Mechanism in Polycrystalline Columbium

by D. P. Gregory and G. H. Rowe

When pure, the body-centered cubic refractory metals work harden at relatively low rates. Since this is undesirable (a lack of work hardening results in structural instability), the authors studied dislocation mechanism which lead to work hardening in body-centered cubic metals. In this report, they present results of activation energy, activation volume, surface slip marking, and transmission electron microscope studies with pure polycrystalline columbium. The surface marking and transmission electron microscope studies showed where the disclocations in individual crystals were located (as free dislocations, in subboundaries, in Frank nets, in tangled networks, or associated with precipitates), and how the dislocation density was distributed between these various locations as a function of strain, temperature, crystal orientation, and strain rate.

Strengthening Mechanism and Alloying Theory for Body-Centered Cubic Metals

by D. P. Gregory and G. H. Rowe

Basically, there are three mechanisms for strengthening pure metals by alloying. The first involves pin-

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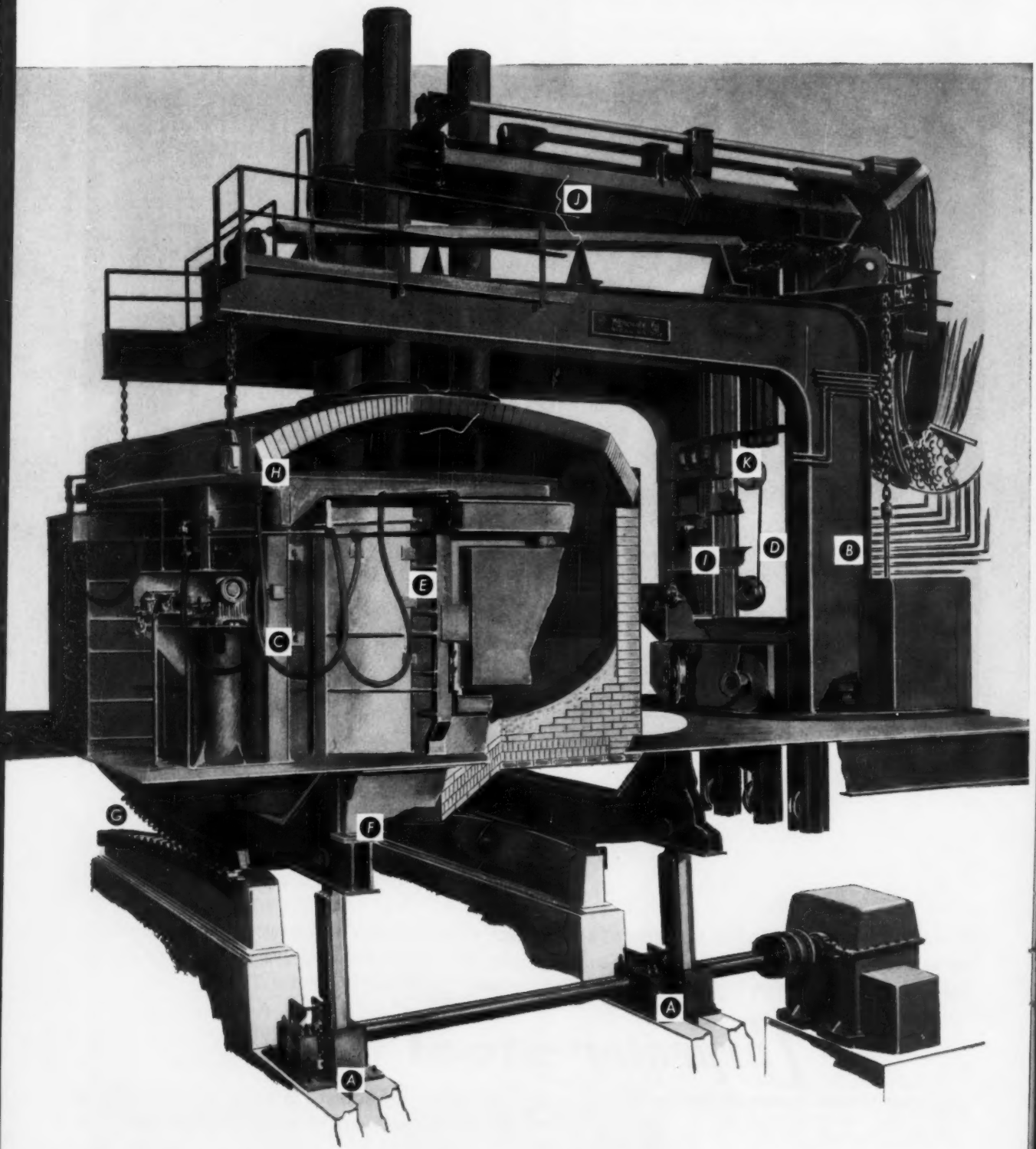

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2. Cage-type shell construction with shell plates loosely attached **(E)** to heavy supporting structure. This construction minimizes shell warping and allows easy replacement of damaged shell plates.

3. Operating mechanism independently supported. The tilting platform on which all operating mechanisms are supported is attached directly to the rockers independent of the shell structure **(F)**. Thus, operating mechanisms are unaffected by shell distortion.

4. Water-cooled, Skew Back Roof ring. This feature **(H)** eliminates the need for special skew-shaped roof refractories.

5. Electrode Mast Safety Device. This spring-loaded, rack-and-pawl-type device **(I)** provides positive protection against damage resulting from electrode winch cable breakage.

6. Square-section, Water-Cooled Electrode Mast Arms. This design **(J)** guarantees a rigid connection between mast and mast arm, thus helping to maintain proper electrode position.

7. Remote-Controlled Electrode Clamps. This device, of the spring-clamp, air-release type, is located inside of the rear section of the water-cooled mast arm where heat cannot affect it.

8. Square-Sectioned Electrode Mast. This design feature **(K)** developed by American Bridge, assures proper guiding and electrode positioning.

9. Rockers. The heavy fabricated steel curved top and bottom rockers **(G)** minimize forward travel during tilting. These rockers are designed so that the furnace will tend to return to horizontal position from any degree of tilt.

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Circle 1571 on Page 48-B

Abstracts . . .

ning the dislocations so that they either cannot move at all, or, if they do move, a frictional drag will result from the movement. The second mechanism places barriers in the path of moving dislocations so that they must bend, climb, or cross slip to pass the barriers. The third mechanism concerns alloying to slow dislocation climb rates.

Recently, transmission electron microscopy has been used to study the strengthening mechanisms in numerous alloys. Since many of these mechanisms have been identified by these studies, the authors discuss them and apply the principles to alloy design. They will show that optimum low-temperature tensile and elevated-temperature creep properties (obtained when these metals are alloyed) employ two or all three of the general mechanisms. Temperature stability and temperature potential of the various mechanisms will be discussed.

Latent Hardening Experiments and Work-Hardening Theories

by U. F. Kocks

The influence of the operation of one glide system upon the subsequent operation of another (on an intersecting plane) was investigated by two methods: uniaxial compression of a cube in two directions, and combined torsion and compression (in varying ratios) of thin-walled prismatic (square or hexagonal) single crystals. The author stresses the exact relationship of the two systems as well as the implication of these results on existing work-hardening theories.

Strain Hardening of Zinc Crystals in Alternating Tension and Compression

by T. H. Alden

To determine the nature of the strain hardening, the author tested single crystals of zinc of several orientations in alternating tension and compression to a plastic shear strain amplitude of 1%, and plotted curves of the stress amplitude versus the accumulated plastic strain.

The behavior at –52° C. (–60° F.) differs from that of copper, tested under similar conditions, by the relatively high stresses to which hardening remains linear. Continued linear hardening reflects the difficulty of dynamic recovery in zinc by the mechanism of cross slip. An ap-

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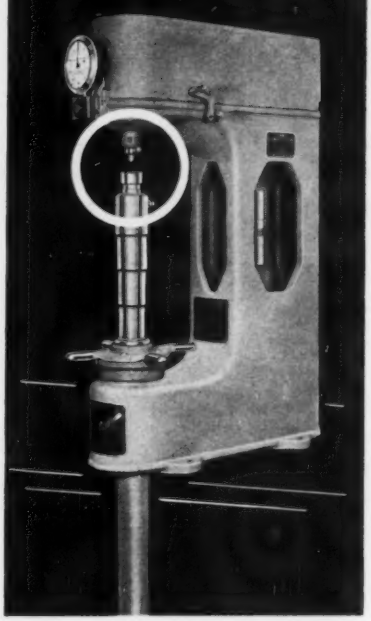

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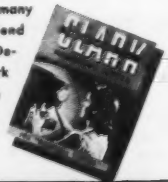

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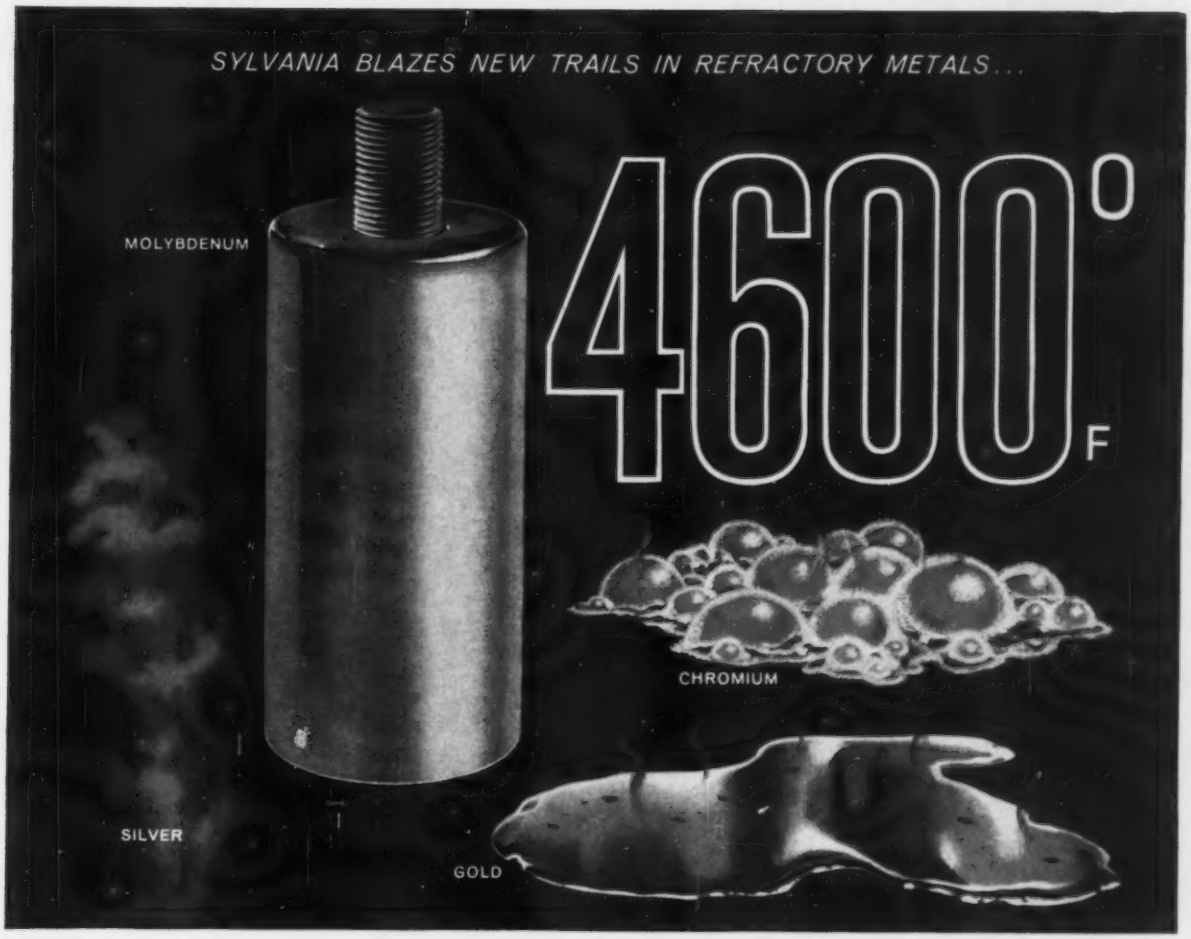

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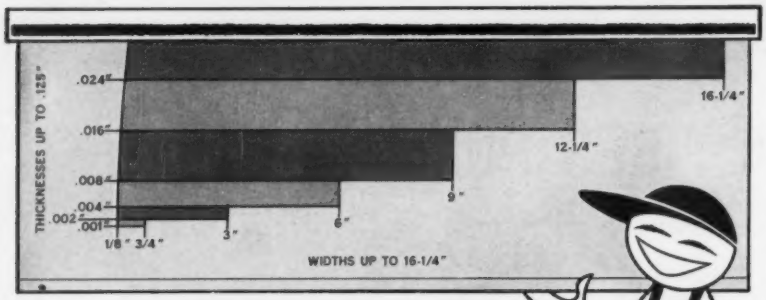

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proximate nonhardening plastic strain condition, suitable for fatigue fracture, cannot be established. Instead, failure occurs by an alternate mode (in this instance, cleavage). These conclusions agree with the observed difficulty of fatigue fracture in zinc at low temperatures.

Fine Particle Effect in Dispersion Strengthening

by G. S. Ansell

Most of the theoretical treatments of the effect of a dispersed second phase upon the yield strength of dispersion strengthened alloys have predicted a relationship of mean free path between dispersed particles to yield strength. Recently, however, investigations of alloys consisting of very fine spherical particles of iron dispersed in a mercury matrix have shown a strengthening effect which appears incompatible with these theories.

This paper concerns the yielding behavior of alloys containing particles where the radius of curvature is so small that the array of dislocations can no longer be considered straight. Calculations based upon this "fine-particle dispersion" model show that the yielding behavior of these alloys is only a function of the volume fraction of the dispersed phase. Consideration of this effect appears to account for the change of yielding behavior observed during aging of precipitation-strengthened alloys.

Phase Relationships and Thermodynamics

Wednesday, October 25 – 2:00 p.m.

An X-Ray Investigation of Alloys of Technetium 99 With Some Transition Elements of First and Third Long Periods

by J. B. Darby, Jr., D. J. Lam, J. W. Downey and L. J. Norton

Little information is available on constitution diagrams involving technetium since this element does not occur naturally. It can be produced, however, as a fission product in the reprocessing of nuclear fuel elements. Recently, sufficient quantities of the stable isotope technetium 99 have become available to permit the use of conventional techniques for determining phase diagram studies of radioactive materials.

An extensive investigation is in progress to determine the solid-solution ranges and the occurrence of

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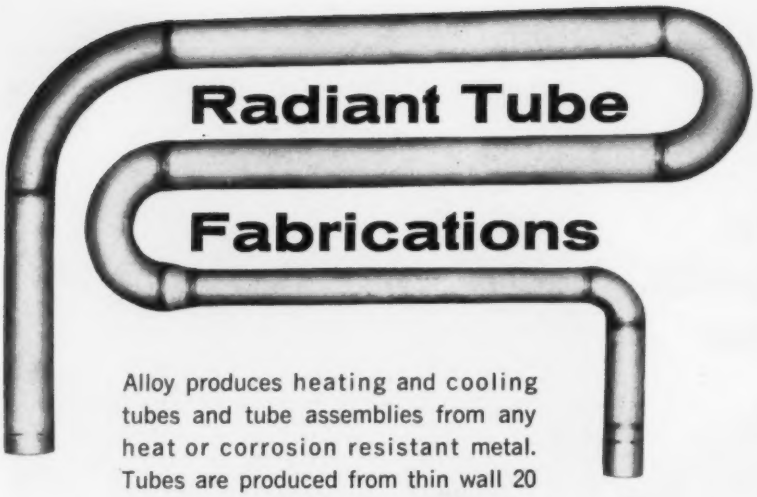

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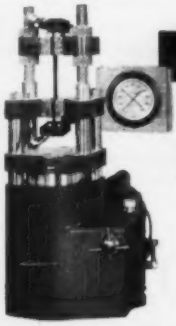

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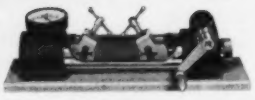

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intermetallic compounds in binary systems with technetium 99 as a component and a transition element of the first or third long periods as the other component. To date, the results indicate that technetium behaves very much like the other members of the manganese group when alloyed with transition elements.

Solubility and Precipitation of Boron Nitride in Iron-Boron Alloys
by R. W. Fountain and John Chipman

This study concerns the conditions under which BN forms from dissolved boron and nitrogen and from dissolved nitrogen and the compound Fe_2B. From the results, the two-phase equilibrium between alpha iron and BN has been established, along with the three-phase equilibrium between alpha iron, BN, and Fe_2B between 950 and 1150° C. (1740 and 2100° F.). The authors also discuss the application of these results to the influence of boron on the resistance of low-carbon steel to strain aging and the hardenability of heat treatable steels.

Deformation — I

Wednesday, October 25 – 2:00 p.m.

Effects of Thermal Mechanical Treatments on Faulting in Some F.C.C. Alloys
by D. E. Mikkola and J. B. Cohen

Deformation twin faults were found in Cu_3Au and 14.3% Al copper alloys deformed at room temperature as well as at low temperatures. The concentration of both twin and stacking faults increased with decreasing temperature of cold work. Since the ratio of twin to stacking faults was about two in both alloys after deformation below room temperature, it appeared that the mechanisms for the two faults were associated.

When filings of the 14.3% Al copper alloy were heated, stacking faults annealed out in two stages. The first stage was characterized by a decrease in fault probability after a short time at temperature, after which no change was observed for long times. Most of the faults annealed out in the second stage; large changes in hardness and microstrain indicated that this latter stage was associated with recrystallization. Twin faults were more stable than stacking faults.

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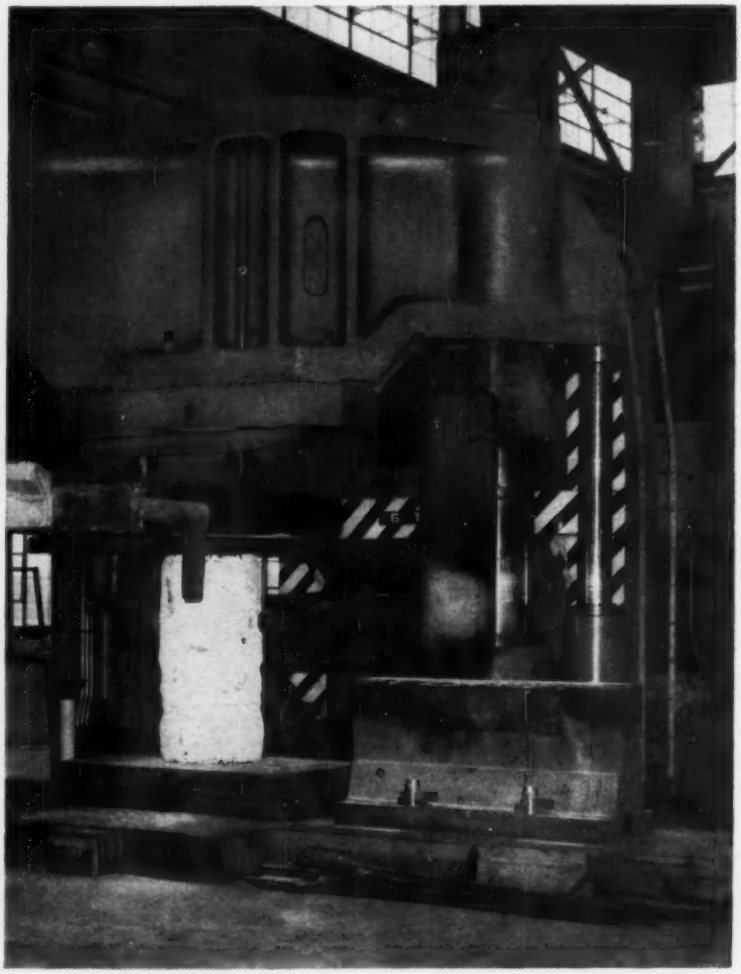
. . . A-L's 2,000 Ton Forging Press

Production equipment specially designed for the job at hand is part of the story. The direct pumping facility and fast, closely controlled action of A-L's unique forging equipment permits greater reductions in area from ingot to billet in a single heating, and results in complete ingot reduction in a relatively short time, with fewer reheats necessary. Coupled with A-L's ability to produce ingots up to 40″, of superior quality as-cast, the capacity of this press to rapidly and *completely* work such ingot grain structure inevitably results in an exceptionally high center quality in the billet, together with a refined grain structure more responsive to heat treatment. Substantially improved mechanical properties are obtained in the forged die blocks, with particular improvement in transverse tensile strength and ductility.



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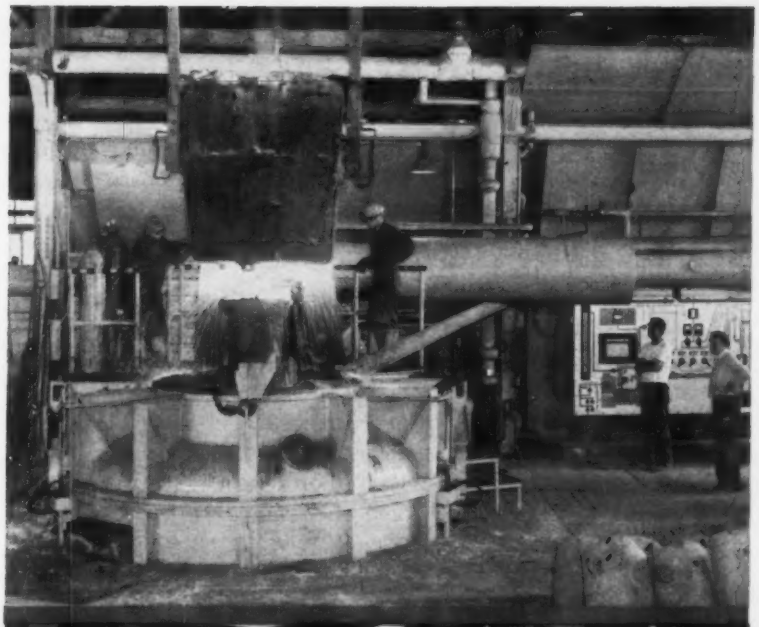
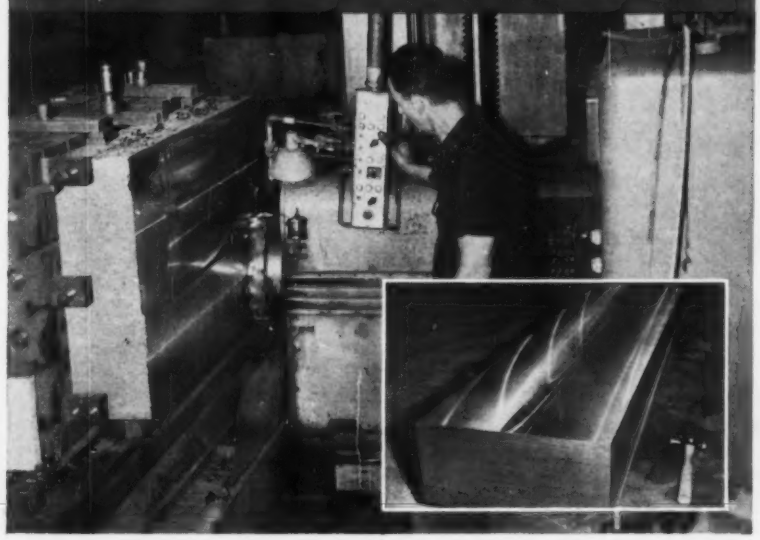




...A-L's Vacuum Degassing

Potomac M Die Steel is vacuum degassed . . . as a matter of routine. Vacuum degassing results in a cleaner steel, without blemishes or subsurface discontinuities . . . those imperfections which often reveal themselves in the die only after considerable machining has been done. Vacuum degassing produces a steel with lower oxygen and hydrogen content, with greatly reduced tendency toward microcrack formation, with fewer nonmetallic inclusions . . . a steel with better, more reliable mechanical properties clear through.

...A-L's Special Melting

For the unusual die applications requiring the ultimate in cleanliness and center quality, Allegheny Ludlum now offers its Consutrode® Potomac M. For requirements involving a super-finish die, the superior cleanliness of this vacuum melted product assures the die maker of an unblemished working surface clear through the workpiece. Equally important, this vacuum melted steel provides an improved transverse ductility in large die blocks, particularly applicable to dies which require the ultimate in toughness and resistance to thermal shock.

...A-L's Machined Finish

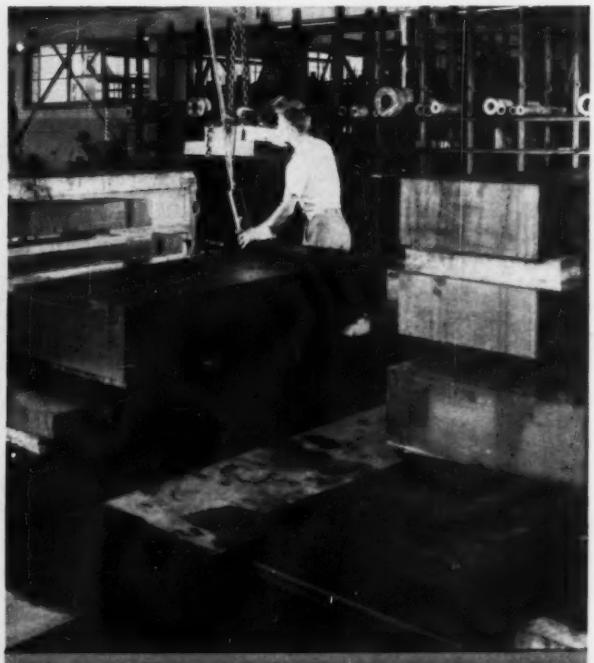
All bars and blocks in the larger sizes are milled to a finish that permits die layout right on the steel we ship. Finished closer to final size, there's much less wasted metal to wind up as chips on the floor of your shop. Allegheny Ludlum Potomac M die blocks are delivered to you free from scale and decarburized surface areas, and ready for your diemakers.

3702-3

AVAILABILITY

Allegheny Ludlum's Potomac M is part of the Steelector Program, a unique system which enables tool steel buyers to select the proper steel on the basis of intended application, and check on the availability of the desired size and shape before any purchase decision is made or any paperwork issued. Individual Data Stock Lists for each Steelector Grade clearly set forth the size and shapes of bars and billets available from stock . . . sizes which will serve the requirements of all users. This is all finished stock . . . over 320,000 pounds of Potomac M . . . on the shelf, ready for you. And, it's backed up by over 180,000 pounds of Potomac M billet stock, ready at the mill for finishing to your specifications, should the size, weight or shape of your order take it out of depot stock category. To learn how you can take advantage of this special stocking plan on tool and die steels, contact your local A-L Representative, and ask him about the Steelector Program and the job-shop availability of special sizes, or write Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.

Back-up stocks of ingots and billets insure job-shop delivery schedules on mill shipments. Here, Potomac M billet stocks at the Dunkirk Plant of Allegheny Ludlum await finishing operations.



A corner of an Allegheny Ludlum Warehouse, with part of the finished stocks of large Potomac M die blocks that permit customers to quote on short delivery jobs without expensive inventories.

STEELECTOR PROGRAM

ALLEGHENY LUDLUM

Tool Steel warehouse stocks throughout the country

AL®

A702-4

Circle 1582 on Page 48-B

Why you'll like being called a liar

Nobody will believe the results you get with the remarkable Hevi-Duty Tagliaferri furnaces . . . but you can laugh all the way to the bank!

Lower costs, improved end products, and easy maintenance make Hevi-Duty Tagliaferri melters and receivers well worth your immediate inspection. Now operating in more than 1100 installations throughout the world, these 60-cycle induction systems are making important contributions to the art of making money.

HERE'S WHY YOU'LL LIKE THE MELTERS

Scrap and foundry returns melted with less than 1% loss

You can produce metals of high quality and controlled analysis from materials of the lowest grade. For both ferrous and nonferrous applications, these systems are available in capacities up to 30 tons.

No products of combustion or impurities added during melt

No products of combustion, sulphur or other impurities are added during melting or pouring. The furnaces are completely covered at all times and metal is poured from beneath the surface.

Controlled stirring for even blending – added strength

The electrical induction currents used to heat the charge also give a *controlled* stirring action which completely homogenizes the melt. Controlled stirring also reduces porosity and produces fine-grained iron of high strength and good machinability.

For nonferrous melting this controlled stirring results in a quiet bath with no turbulence at the metal surface. Oxidation and gas absorption are reduced. For brass melting, zinc losses are held to a minimum.

Low power consumption for low operating costs

The Hevi-Duty Tagliaferri induction furnaces use electrical power efficiently. These furnaces have a higher uncorrected power factor than competitive induction units. Thermal efficiency is about 78%.

Furnaces can start from cold – shells are interchangeable

Melting furnaces start from cold. No hot metal is needed. When it is necessary to change alloy or to interrupt operation, furnaces can be emptied completely.

Maintenance and cleaning are simplified

The channels in the non-ferrous furnaces are *easy* to inspect or clean; simply tilt the furnace forward and open the channel doors. A heel of molten metal can be left in the furnace during cleaning

Relined furnace shells can be installed without disconnecting electrical or hydraulic equipment.

HERE'S WHY YOU'LL LIKE THE RECEIVERS

Increased tensile strength after 20 minutes

Hevi-Duty Tagliaferri electric induction receivers take metal from the cupola and, in 20 to 30 minutes, homogenize it to produce iron of higher tensile strength.

Improved machinability

Metal refined in these receivers is fine-grained with a uniform structure resulting in good machinability.

Fluidity of metal increased by receivers – lower pouring temperature possible

Mold details fill more completely. Thinner sections can be cast successfully. And, products can often be redesigned to use less metal.

No loss of alloy

Alloying is accomplished in Hevi-Duty Tagliaferri receivers without loss of alloys. Raw iron from the cupola can be held in the receiver and analysis carefully controlled. Holding is possible for as long as 48 hours without analysis change.

Temperature controlled closely

Temperature can be adjusted within the receivers to best suit pouring conditions. Proper metallurgical analysis can be achieved. Steel scrap can be added to adjust the chemistry.

Get the full details

For information on Hevi-Duty Tagliaferri systems contact your nearest Hevi-Duty sales engineer or write Hevi-Duty Electric Company, Watertown, Wisconsin. Request Ferrous Bulletin 6051 — or Nonferrous Bulletin 6052.

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Circle 1583 on Page 48-B

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Circle 1584 on Page 48-B

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gives longer life, greater strength, lighter weight

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Circle 1585 on Page 48-B

The Influence of Grain Size and Specimen Size on Unidirectional Polycrystal Plasticity
by R. W. Armstrong

The cumulative effects of specimen size and grain size are responsible for the increased strength of a polycrystalline aggregate above the single crystal strength at temperatures and strain rates where diffusion does not play a large part in the deformation.

The "specimen size" effect occurs when few grains are present in a specimen cross section; this effect is due mainly to the orientation dependence of crystal plastic flow. The "grain size" effect occurs in polycrystalline materials because grain boundaries are obstacles to the initiation of bulk yielding and subsequent propagation of plastic flow.

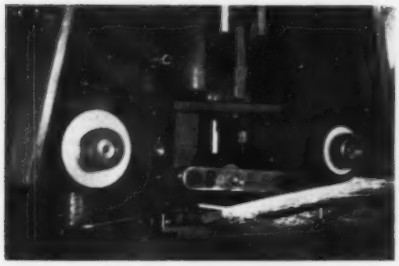
Micro-Strain Behavior of Aluminum
by R. C. Ku and Norman Brown

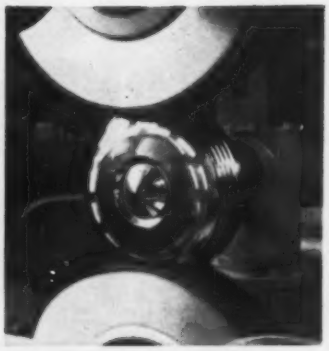
For this report, the authors investigated the deformation of aluminum single crystals and polycrystals in the region of microyielding. The lowest stress at which dislocation movement could be detected was associated with the average frictional stress needed to move dislocations on the order of several to a thousand atomic distances. The stress at which a permanent strain was first detected was associated with the generation of dislocations, and the interaction of the moving dislocations with the forest dislocations.

Deformation Twinning and Stacking Faults in Body-Centered Cubic Transition Metals and Alloys
by E. E. Underwood

For this report, the author studied the twinning characteristics of nine transition metals and fifteen alloys based on molybdenum, tungsten, and chromium. The actual hardnesses of the alloys (and the twinning intensities) decrease in the order of the base metals, tungsten, molybdenum and chromium. Twinning apparently occurs with small strains, increases rapidly, with continued straining, then levels off. For twins to develop, it appears that a small, finite strain is needed.

ACME IN ACTION





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Here are eight good examples of Acme finishing machines in action—automatics and semi-automatics—performing grinding, deburring, polishing and/or buffing operations on a wide variety of parts and products. Yet different though they may be, all of these jobs—and countless others, too—have one thing in common: *Because the machines are* "ACMES", *the finishing operations are being performed quickly, easily, uniformly—and at lower cost than was realized with previous methods.*

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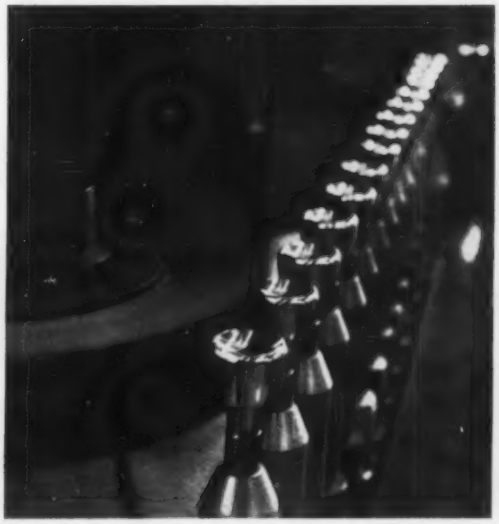

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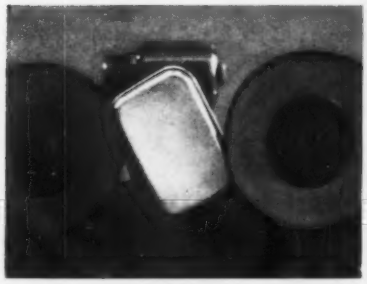

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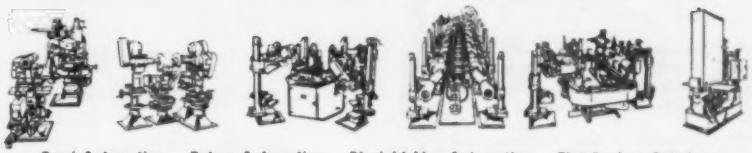

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Circle 1608 on Page 48-E

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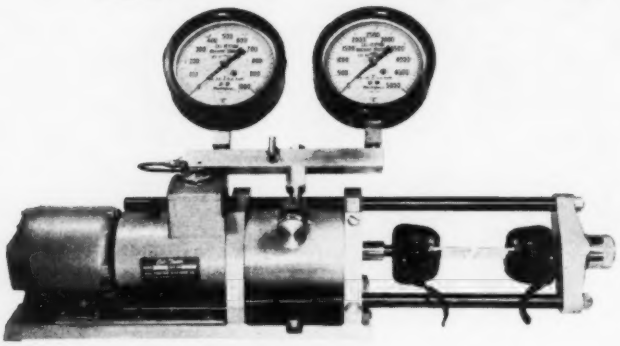

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Circle 1587 on Page 48-B

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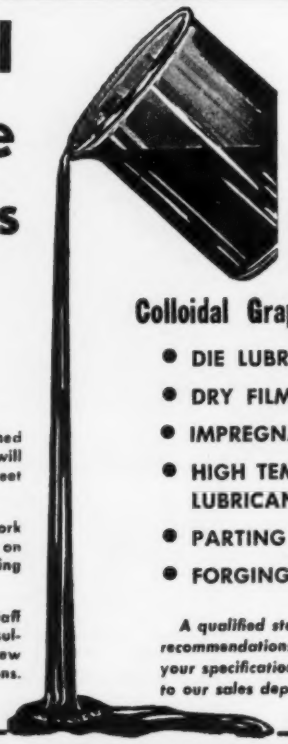

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Circle 1588 on Page 48-B

Yielding and Flow of Sapphire Crystals
by Hans Conrad

The author investigated the plastic flow of sapphire crystals in tension at various temperatures and strain rates, and found that the stress-strain curves exhibited a proportional limit, followed by discontinuous yielding and subsequent flow with strain hardening. The results supported Weertman's dislocation climb mechanism as the rate-controlling mechanism for yielding as well as subsequent flow.

Oxygen Precipitation Effects on the Deformation of Dislocation-Free Silicon
by J. R. Patel and A. R. Chaudhuri

Silicon crystals grown from quartz crucibles usually contain small amounts of oxygen. When specimens from such crystals are heat treated for prolonged periods, oxygen appears to precipitate forming a quartz-like structure. This precipitation of oxygen affects tensile deformation characteristics in that it lessens the large yield drop normally observed in as-grown silicon crystals at high temperatures. Since the measured velocities of dislocations are not altered by heat treatment, precipitation may either increase the initial dislocation density of the crystals, or provide nucleation sites for the generation of dislocations during deformation.

In dislocation-free crystals of silicon, precipitation increases the initial dislocation density, the degree depending on the heat treatment time. For crystals that contain a few dislocations, oxygen precipitation provides active sites for the generation of dislocations during deformation.

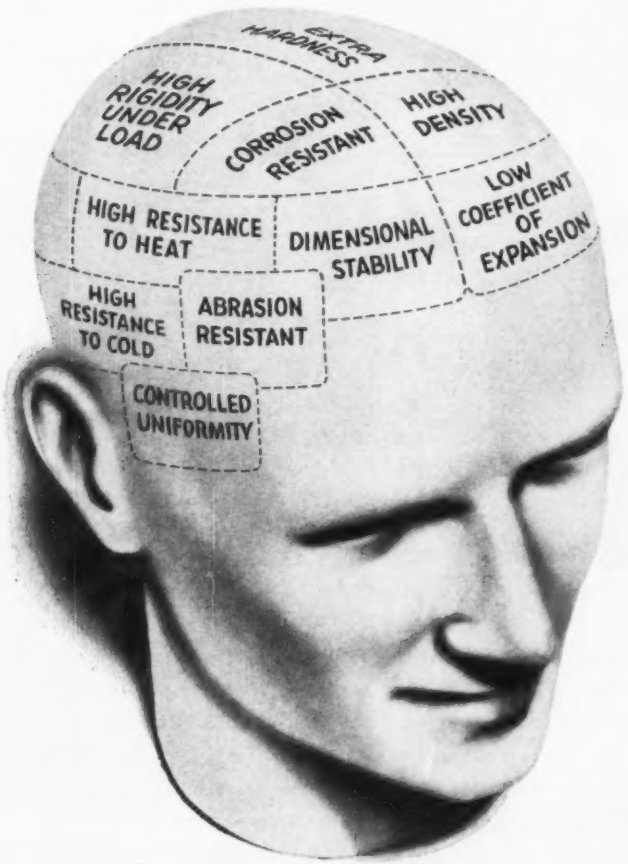
Diffusion

Wednesday, October 25 — 2:00 p.m.

Thermal Diffusion of Vacancies in Pure Gold
by P. G. Shewmon

In an initially homogeneous alloy, the redistribution of solute that occurs on annealing in a temperature gradient is called thermal diffusion. For pure gold, the two diffusing species are gold atoms and vacancies.

"Whatever the mind of man can conceive and believe, the mind of man can achieve..."



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In the present work, gold wires were held in a temperature gradient, and marker movement occurred indicating a net flux of atoms toward the hot end.

Interstitial Diffusion in Dilute Ternary Austenites

by J. S. Kirkaldy and G. R. Purdy

For the iron-rich ternary austenite, the interstitial carbon solute is very much more mobile than other substitutional solutes. This work concerns the Onsager reciprocal relations for the systems Fe-C-Si, Fe-C-Mn and Fe-C-Ni.

Simulation of Banding in Steels

by R. J. Brigham, J. von Destinon-Forstmann and J. S. Kirkaldy

The authors, by constructing three-layer diffusion couples to simulate the compositional variations which occur in commercial mild steels as a result of interdendritic segregation, have been able to examine quantitatively the banding behavior in the ternary systems Fe-Si-C, Fe-Mn-C, Fe-Ni-C, Fe-Cr-C and Fe-P-C as to the intensity of carbon segregation which occurs both in the austenite range and during the subsequent austenite to ferrite transformation. Their results confirmed that the segregation of carbon which occurs before transformation is due to the equalization of the carbon activities. As expected from thermodynamic data, silicon, nickel and phosphorus-rich regions rejected carbon while manganese and chromium-rich regions attracted it.

Self-Diffusion in Liquid Tin

by R. A. Swalin and C. H. Ma

The self-diffusion of tin in tin has been investigated over a wide temperature interval to examine the general validity of the fluctuation theory of diffusion. The diffusion constant was determined by the appropriate solution of Fick's second law. Upon plotting the data (as the logarithm of the diffusion constant against the reciprocal of absolute temperature), the authors noted that considerable positive curvature occurred at elevated temperatures.

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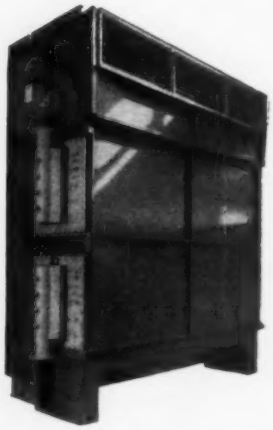

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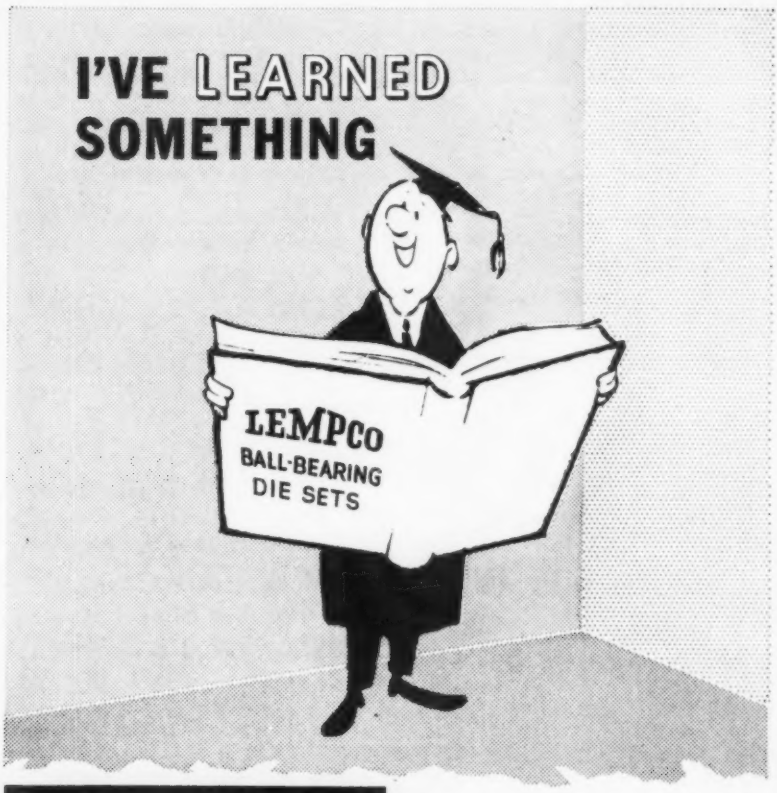

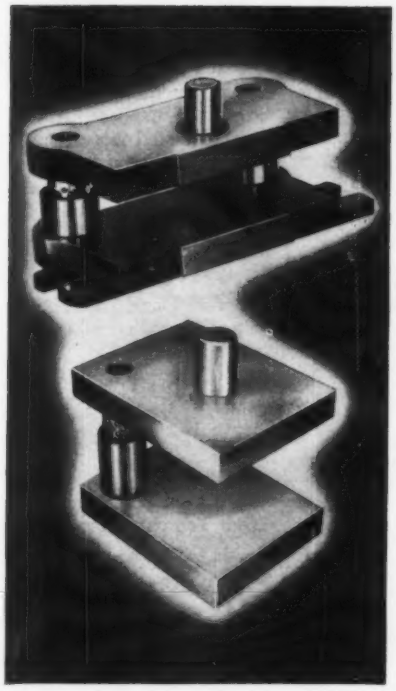

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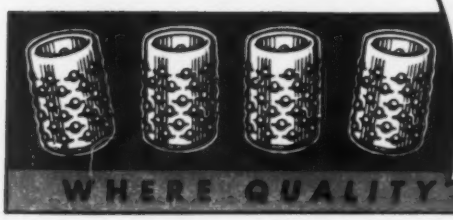

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BOOTH 114

Circle 1592 on Page 48-B

Since curvatures have been reported for mercury and for indium, authors believe that the general features of the fluctuation model are valid.

Diffusion of Sulfur in Single Crystals of Lead Sulfide as a Function of Stoichiometry

by M. Seltzer and J. B. Wagner, Jr.

The authors have studied the diffusion of radioactive sulfur into single crystals of lead sulfide as a function of deviation from stoichiometry, and defect concentration introduced by doping to determine the predominant mechanism by which the anion diffuses in this compound. Measurements have been made using crystals of stoichiometric composition, and on others with excess sulfur and excess lead atoms. The sulfur-excess specimens showed the highest diffusivities in this temperature range, while lowest diffusion coefficients were obtained from the lead-excess specimens.

Diffusion measurements have also been performed on specimens doped with 0.5 or 0.05 mole % Ag_2S_3 or Bi_2S_3, which were annealed under the same conditions as those required to obtain undoped stoichiometric PbS crystals.

These data appear to rule out the possibility that the negative ion diffuses by jumping into isolated negative ion vacancies. The importance of neutral vacancy pairs as a mode for anion diffusion is considered.

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Circle 1593 on Page 48-B

Deformation — II

Thursday, October 26 – 9:00 a.m.

Mechanical Properties of NaCl-AgCl Alloys

by R. J. Stokes and C. H. Li

Both NaCl and AgCl possess rock salt structures with similar lattice parameters. However, single crystals of the pure salts show markedly different mechanical behavior at room temperature; NaCl is ductile only when the surface is flaw-free while AgCl is always ductile.

When single crystals of NaCl-AgCl alloys were tested in compression, the authors observed that the curve of yield strength versus composition followed a bell shape. In the 15% NaCl and 15% AgCl regions, strength increased rapidly to 25,000 psi., a value which was maintained between 25% and 75% NaCl. This high strength was caused by precipitation hardening.

Some Observations of Yield Points in Aluminum at High Temperatures

by R. H. Bush and R. A. Huggins

Pronounced yield points have been observed for single crystals of high-purity aluminum tested in tension between 450 and 650° C (840 and 1200° F.). According to the results, the magnitude of the yield point depended on the test temperature, the extension rate, the amount and type of prior strain, and, indirectly, the sample orientation. The author, discusses the observed phenomena in terms of existing theories of yield point mechanisms.

THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

1 . . 5 . . 10 . . 15 . . 20 . . 25 . . 30 . . 35 . . 40 . . 43

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GENERAL ALLOYS COMPANY

401 West First St., Boston, Massachusetts

the only producer of both heat resisting castings and fabrications

Circle 1594 on Page 48-B

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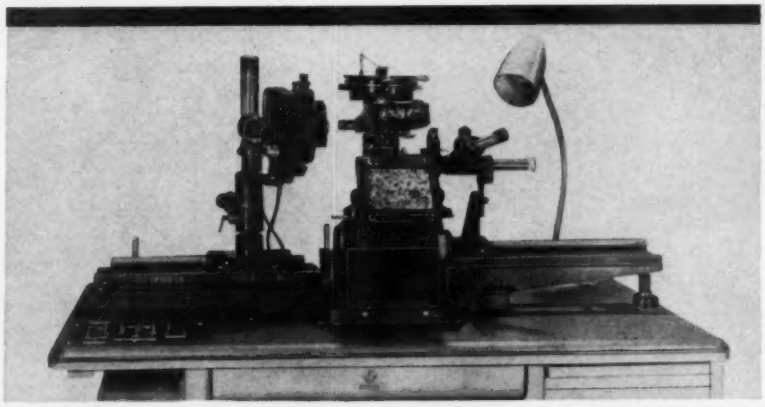

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Versatile **Reichert** Metallographic Microscopes and Metallographs equipped to your requirements: interferometry, interference contrast, phase contrast, micro hardness tests, grain size measuring equipment, high-temperature microscopy, five light sources, polarized light and Polaroid photography (2¼ × 3¼", 3¼ x 4¼" and 4 x 5").

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Circle 1595 on Page 48-B

Dislocation Damping in Deformed Low-Carbon Steel

by W. J. Bratina and D. Mills

The authors studied the effect of plastic deformation on dislocation damping in A.I.S.I. 1020 through the use of ultrasonic techniques in the low megacycle frequency range.

Of main interest was the dislocation damping induced by elastic strain; this was studied under various conditions. All the results obtained appeared to be explained by a dislocation loop-pinning point interaction.

Metallographic Studies of the Fatigue Process in Copper

by H. M. Bendler and W. A. Wood

The surfaces of crystalline OFHC copper under fatigue have been observed by optical and electron metallography. At various stages, specimens which had been cycled at different amplitudes and for different fractions of their fatigue life were examined for surface deformation (slip bands, fissures, and fatigue cracks). As for results, when a tensile stress was superimposed on the polycrystalline specimen while it was being fatigued, development fissures grew rapidly and the fatigue life markedly shortened. This and other factors are discussed by the author.

Effect of Hydrogen on the Creep Properties of Nickel-Base Materials at Elevated Temperatures

by H. E. McCoy and J. R. Weir

The proposed use of hydrogen as a reactor coolant makes it imperative to know how structural materials will act in hydrogen environments at elevated temperatures. In this paper, which concerns the properties of nickel-base materials (primarily "A" nickel and Inconel), the characteristic room-temperature hydrogen embrittlement which occurs in many of these alloys is discussed briefly. According to the data that are given, the high-temperature creep strength of nickel and Inconel was less in hydrogen than in argon. The magnitude of this effect appeared to be dependent upon the rate of deformation, with larger effects being observed at lower strain rates.

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If you're interested in "moving up the ladder" in your present company . . . if you want to become part of the "decision-making" team in your organization . . . broaden your knowledge of the metal-working industry . . . improve your present position and income . . . NOW is the time to investigate the advantages of enrollment in ASM'S METALS ENGINEERING INSTITUTE. Today, MEI offers more than 20 courses in metals subjects ranging from "Elements of Metallurgy" to "Metals for Nuclear Power". These comprehensive and inexpensive courses prepared and compiled by noted specialists in the fields of materials and processes, can be taken at home under the watchful guidance of the expert MEI staff. The Metals Engineering Institute courses of *your* selection can be a major step forward to a rewarding career in the metal-working industry.

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Ultra-high vacuum-EB evaporator.

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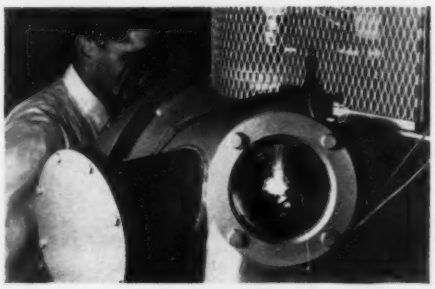
If you are interested in vacuum electron beam processing, either in the development or production stages, check with NRC. Our sales engineers can help you in practical discussions of your needs; complete electron beam laboratory facilities are available on a per diem basis.



Vacuum-electron beam welder.

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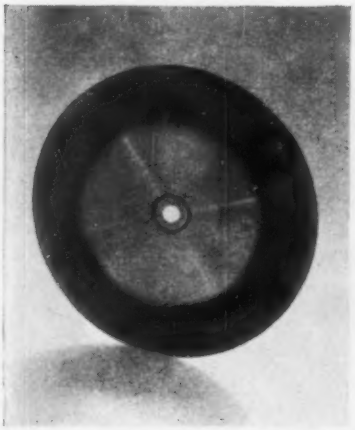
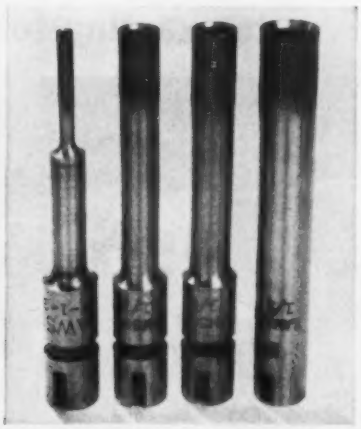
Linde Coatings & materials News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Long wear for precision cutting parts now comes in thin coatings—.001" thick





Two important industrial cutting tools whose working lives have been multiplied by LINDE Flame-Plating tungsten carbide coatings: Rubber skiving knives (l.) and paper drills.

SUPER-THIN coatings of tungsten carbide and aluminum oxide—in the .00075" to .002" range of thickness—now keep many industrial cutting surfaces on the job many times longer than previously, yet preserve the precision fit needed for optimum cutting. The result: important savings in downtime and operating costs.

These tough, long-life precision coatings are applied by LINDE's Flame-Plating process, which "blasts" molten particles of tungsten carbide onto specified areas of wearing surfaces until the particles are built up to the desired degree of thickness.

Typical examples of longer wear

Because their cutting surfaces are Flame-Plated with tungsten carbide coating, rubber skiving knives that formerly required resharpening after every shift now stay in use 15 times longer. The knives also have the advantage of a self-sharpening effect. As the softer steel base wears more rapidly than the hard, tungsten carbide coating, a sharp edge is always presented to the material being cut.

Tungsten carbide coating enables serrated knives used in cutting plastic sheeting to process three times as much material before the first re-sharpening is necessary.

A coating of .001" thickness on the inside cutting surface of surgical shears has reduced their rate of wear by as much as 33 percent.

Flame-Plating proved so revolutionary for household cutlery that the manufacturer built his merchandising theme around *"The Greatest Development in 2000 Years of Cutlery Making—a Cutting Edge of Tungsten Carbide."*

Solves many wear problems

Tungsten carbide coatings of microinches thickness are equally effective wherever metal parts or working surfaces are exposed to abrasion, galling, erosion, fretting, corrosion, or high-temperature wear. Coatings are applied by the LINDE's 6,000-degree Flame-Plating process without distortion of the work piece or changes in properties of base metals.

For full information on Flame-Plating for your particular application, check and mail the coupon below.

Need to production-polish tungsten carbide surfaces?

It's easy with LINDE metallographic production-polishing aluminas—available in grades for three types of finishing: For high stock removal, 1 micron C; for moderate stock removal and ¼ rms finish, 0.3 micron A; for super polish, 0.05 micron B.

LINDE has developed special techniques for production-polishing of semiconductors and soft metals (such as brass), also new ideas for production-polishing hard metals, including micrometer anvils, hardened bearing races, routine metallographic samples. Get help with polishing techniques to meet your requirements. Send coupon below.

Jet planes landed by ruby-against-sapphire wear pads

In the automatic landing computer of a modern jet interceptor, a tiny ruby ball held to tolerances of 30 millionths oscillates against a synthetic sapphire plate flat to 1/10 light band, as a reference plate for a computer to translate radar approach signals into hydraulic actions.

Approximate size: Ruby ball, sapphire plates.

A similar wear surface bears on the cam head. Certain fly wheel governors also have sapphire wear surfaces.

This 70,000 to 300,000 psi LINDE material has a hardness second only to diamond, unlubricated static friction coefficient of .18, and dynamic of .08 against itself in moderate loads. It is economically suited for wear applications such as gage points, textile guides, optical inspection flats, and flow valves. Send coupon for information.

CHECK—CLIP COUPON—ATTACH TO BUSINESS LETTERHEAD

Linde Company
270 Park Avenue
New York 17, N. Y.

Please send data on the items checked:

- ☐ LINDE Flame-Plating Process
- ☐ LINDE Alumina Abrasive Powders
- ☐ LINDE Synthetic Sapphire & Ruby

UNION CARBIDE

LINDE COMPANY

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NUCLEAR GRAPHITE NEWS
from NATIONAL CARBON COMPANY

DIVISION OF UNION CARBIDE CORPORATION, 270 PARK AVENUE, NEW YORK 17, N. Y.
OFFICES: Birmingham, Chicago, Houston, Los Angeles, New York, Pittsburgh, San Francisco. In Canada: Union Carbide Canada Limited, Toronto

NO OTHER MATERIAL HAS SO MANY USEFUL NUCLEAR PROPERTIES

- EXCELLENT STRUCTURAL MATERIAL
- RESISTS CORROSION
- RESISTS THERMAL SHOCK
- EASILY FABRICATED
- HIGH MODERATING QUALITIES
- STRENGTH INCREASES WITH TEMPERATURE RISE

GRAPHITE CORE FOR HANFORD NPR COMPLETED BY NATIONAL CARBON

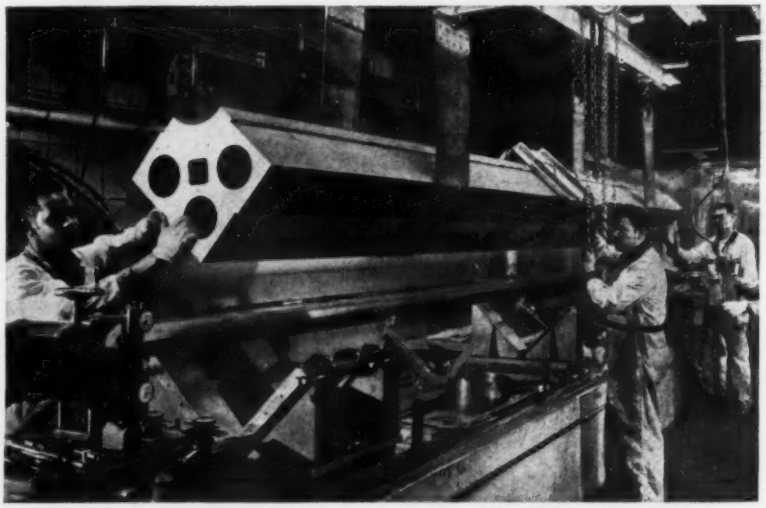
Loading last pallet of moderator bars for the NPR

The task of producing and machining 5 million pounds of high-purity nuclear graphite for the New Production Reactor at Hanford, Washington, has been completed by National Carbon Company.

The entire output was machined to close tolerances, with the thousands of moderator bars ranging in size from 2 x 3 x 48 inches to 6 x 6 x 48 inches. Total ash content was less than 10 ppm.

The New Production Reactor core is another outstanding achievement by National Carbon for the nation's growing reactor program.

4400-lb. graphite columns machined to exacting tolerances for EGCR



Swinging near-20-foot-long EGCR moderator column of "National" nuclear graphite into position for inspection after boring of fuel channels through entire length.

Machining by National Carbon Company of 120 graphite moderator and reflector columns comprising the Experimental Gas Cooled Reactor for the AEC at Oak Ridge, represents a major accomplishment in the production of nuclear components.

General machining specifications for the giant-size columns, designed for the 15-foot, 10-inch diameter core of the EGCR, called for a 125-microinch surface finish. The columns are the longest pieces of nuclear graphite ever produced.

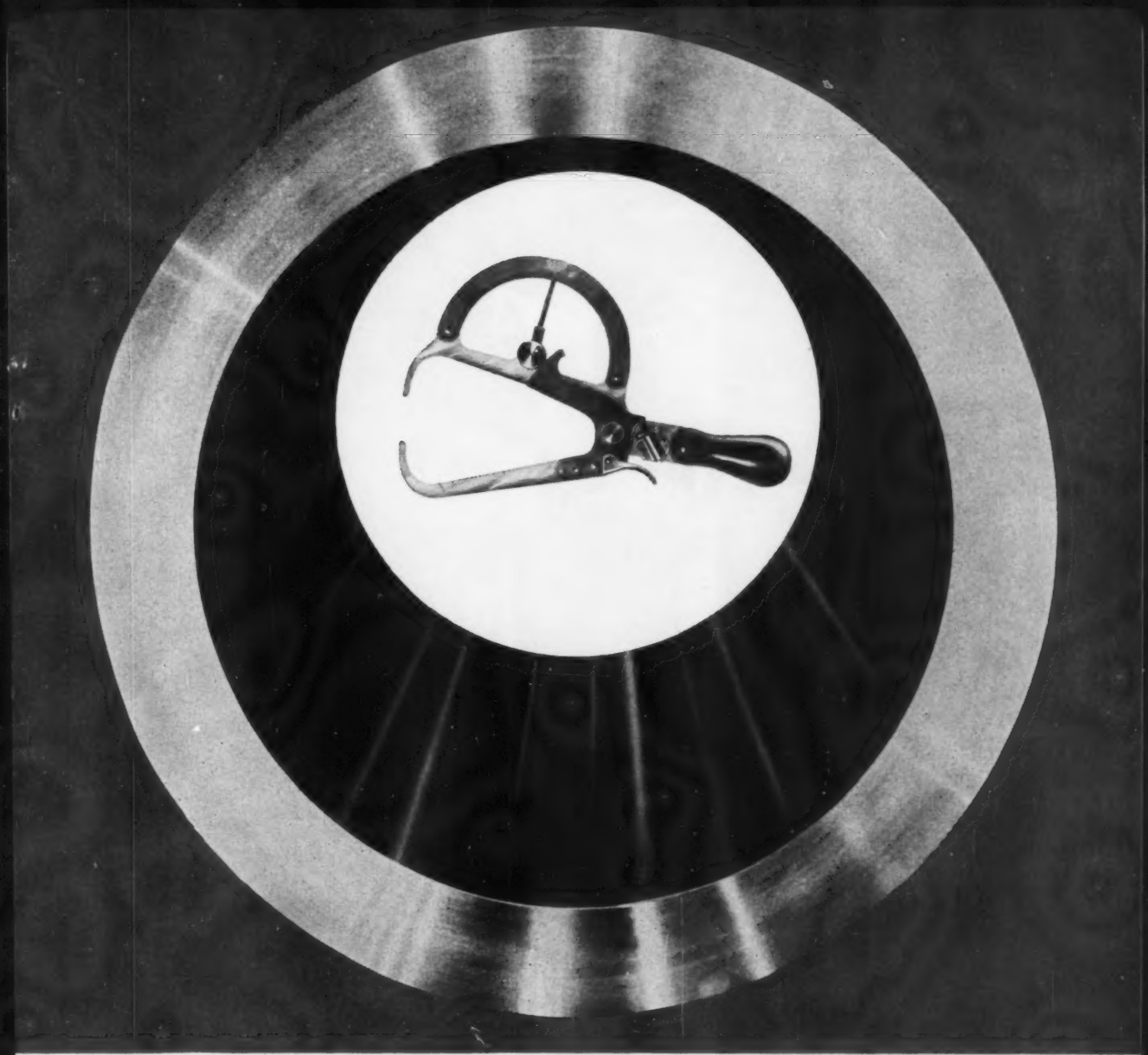
Each moderator column, before machining, measured approximately 20 feet long by 17½ inches square, and weighed some 4400 pounds. Initial machining reduced each column to 16.3 inches square by 19 feet, 4 inches long, with final weight ranging from 2250 to 3600 pounds.

Aside from the boring of numerous precision holes of varying diameters and lengths—such as experimental, control rod, and flux scanning channels; neutron source and thermocouple holes—the most remarkable feat of machining was the boring of the fuel channels. In this operation, 234 holes, 5.25 inches diameter, were bored through the entire length of the columns, with hole diameter held within 0.030-inch, and hole location at each end within 0.010-inch.

After completion of precision machining, each piece passed a purity and flexural load test and was carefully packaged and safely delivered to the customer's plant site.

"National" and "Union Carbide" are registered trade-marks for products of
NATIONAL CARBON COMPANY
UNION CARBIDE

Circle 1597 on Page 48-B



NEW SIZE RANGE SURPRISE!

HERE'S A NEW PROCESS in centrifugally spun tubing that offers you greater freedom in design. It's ACIPCO CERAM-SPUN®... the new ceramic mold process* that is not limited by equipment sizes!

NOW, YOU CAN ORDER almost any combination of sizes you require. ACIPCO CERAM-SPUN® tubes offer O.D.'s from 2.25" to 50"; and wall thicknesses from .25" to 8". As-cast lengths are furnished from 4 feet to 20 feet, longer lengths are made by welding.

THINK OF HOW MUCH this process can save you! You'll avoid the cost of unnecessary metal waste, and excessive machining charges. And ACIPCO's complete "under one roof" operations — including heat treating, machining and welding — offer many additional economies. No need for the delays and excessive costs that often result in buying from multiple sources.

If you design, manufacture or use tubular component parts, it will certainly pay you to investigate the versatility of ACIPCO CERAM-SPUN® tubing and the flexibility of ACIPCO's integrated facilities. Contact **ACIPCO STEEL PRODUCTS,** Division of American Cast Iron Pipe Company, Birmingham 2, Alabama.

*Patent applied for

ACIPCO CERAM-SPUN®
STEEL TUBING

Circle 1598 on Page 48-E

Step by step, Grumman Aircraft saves with Du Pont "Cronar"* films

Grumman Aircraft Engineering Corporation uses Types 506 and 510 Day-Pak to inspect construction in the Hydrafoil ship – all-welded 90-ton vessel whose J-79 turbine engine will move her at speeds up to 80 knots.

Grumman finds that Day-Pak cuts inspection costs and adds convenience. Radiographer Lenard J. Herte says, "Day-Pak was handled without darkroom loading . . . very versatile . . . 5-inch width perfect for the keel."

Group leader Eugene Burgess positions the 5-inch width film for a keel picture, in the 2nd photo above. He and Supervisor of Nondestructive Testing Morton H. Weinberg are shown viewing the Du Pont films in the photos that follow. Mr. Weinberg says, "Du Pont film has given us dependable results for 15 years."

The unique clarity of CRONAR films—plus the consistency of their emulsion and stability of their base—adds to the accuracy and economy of Grumman's testing. These films are packaged in a polyethylene pouch for safe transport and storage.

To learn more about Du Pont films and other fine industrial x-ray products, write E. I. du Pont de Nemours & Co. (Inc.), Photo Products Department, Wilmington 98, Delaware. In Canada: Du Pont of Canada Limited, Toronto.

*Du Pont registered trademark for its polyester photographic film

Circle 1599 on Page 48-B

DU PONT

Better Things for Better Living
. . . through Chemistry

Huntington Alloys

High-temperature properties of INCONEL Alloy X-750 solve many severe metal-service problems

High strength and hardness from —423°F to 1500°F and above... resistance to oxidation and corrosion... low creep and relaxation rates combine to make INCONEL* Alloy X-750 (formerly designated INCONEL "X" Alloy) the preferred material for many exacting applications.

High strength and low creep rate

The strength of INCONEL nickel-iron-chromium alloy X-750 is obtained by age-hardening. Hot rolled bar stock, when aged, has a tensile strength around 180,000 psi at room temperature. At 1200°F, tensile strength is still above 140,000 psi.

At 1350°F, the stress required to produce a minimum creep rate of 0.01 percent per 1000 hours is 30,000 psi. This low creep rate, coupled with the low coefficient of expansion and resistance to high temperature corrosion have led to the wide use of INCONEL alloy X-750 for operating parts having small clearances at high temperatures.

Excellent spring properties

Springs made from INCONEL alloy X-750 give outstanding service in high temperature applications. Because of the high strength, low relaxation rate, and oxidation resistance of the alloy, springs can be made for use at temperatures up to 1200°F. Test springs made from cold-drawn wire, when heat-treated, showed a relaxation of only 5.6% after 28 days at 20,000 psi and 1200°F.

Fabrication and availability

Despite its high strength, alloy X-750 is ductile and can be fabricated by conventional procedures. It is available in all common mill forms from forging stock to small diameter wire and tubes.

Huntington metallurgists and engineers have accumulated a wide range of information concerning the performance and characteristics of this alloy in many applications. This data can guide you in making the most of its outstanding characteristics.

High temperature strength, oxidation resistance, and low relaxation rate... three reasons why INCONEL alloy X-750 springs are used for service to 1200°F.

What are your metal problems?

Can you use an alloy that combines outstanding corrosion resistance and exceptional high and low temperature properties... an alloy that is readily available in all common mill forms? For detailed information on how INCONEL alloy X-750 meets these and other requirements, write for Technical Bulletin T-38.

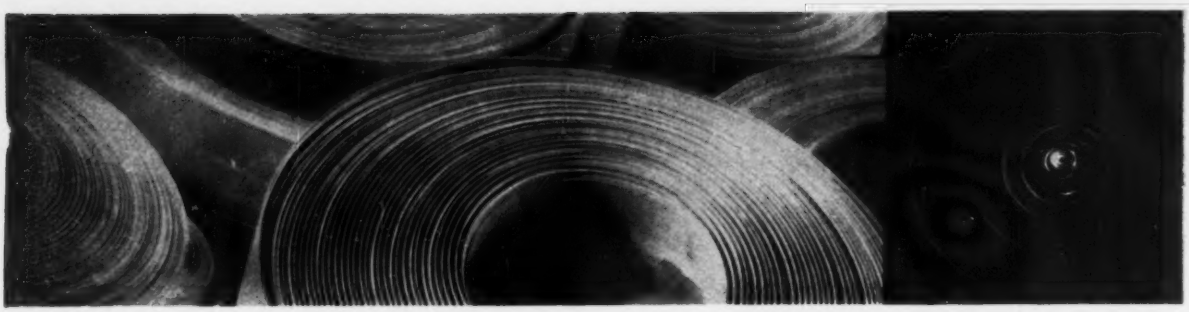
HUNTINGTON ALLOY PRODUCTS DIVISION
The International Nickel Company, Inc.
Huntington 17 INCO **West Virginia**

*Registered trademark

INCONEL®

NICKEL-CHROMIUM ALLOYS

Circle 1600 on Page 48-B



How they're using

Wallace Barnes Cold-rolled Specialty Steels

1. *In Three Drawing Stations*

The part shown in illustration one was made from .59 – .74% carbon steel in three drawing stations. From .70 – .80% carbon, this piece should have four or five drawing stations. The piece could be made from .90 – 1.05% carbon, but would require seven drawing stations with fully annealed steel.

2. *Blanked on 45° Angle*

The stamping shown in the second illustration was made from .70 – .80% carbon spring steel. It was blanked and pierced on a 45° angle, with small holes pierced to prevent fracture in later forming and bending. It was then given severe secondary forming. The small tab shows "orange peel" and probable fracture would occur if the part were formed from .90 – 1.05% carbon.

3. *All Flanging One Operation*

Our third part is a gun stamping made from .70 – .80% carbon with a sharp bend with the grain in one stroke of the press. Higher carbon will fracture due to its less ductile qualities.

4. *Thirteen Steps Progressive*

The fastener shown in the fourth illustration was made from the .59 – .74% carbon steel, the only spring steel which would take the bends and draws to which it is subjected here. All the higher carbon steels were rejected because they failed under the cold-work necessary to produce the two small extrusions. It took seven reductions to bring these extrusions within tolerance. There were thirteen steps total in the progressive die.

These examples show how proper steel selection may save operations and insure satisfactory performance. Among the many sizes and types of Wallace Barnes cold-rolled specialty steels is the right one for your application.

Send for brochure illustrating various types of products made from Wallace Barnes Specialty Steels.

Wallace Barnes Steel Division

Bristol, Connecticut

Associated Spring Corporation

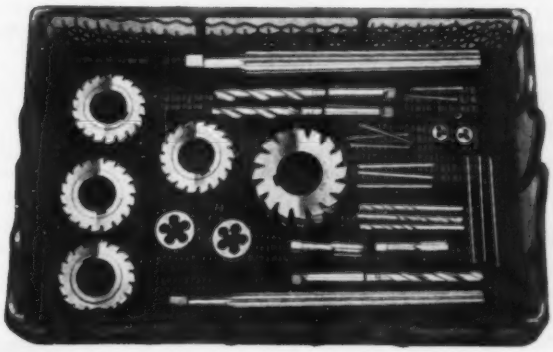
Circle 1601 on Page 48-B

new process **heat-treats high speed steel**

AT 1/2 SALT BATH COSTS,
PRODUCING CLEAN, BRIGHT PARTS!

VFC-150
2400° F. Maximum
Operating Temperature

- New Heat-Treat Process Controls the Surface Chemistry.
- Processed Parts are Always Bright.



BRIGHT HARDENING M-2 TOOLS

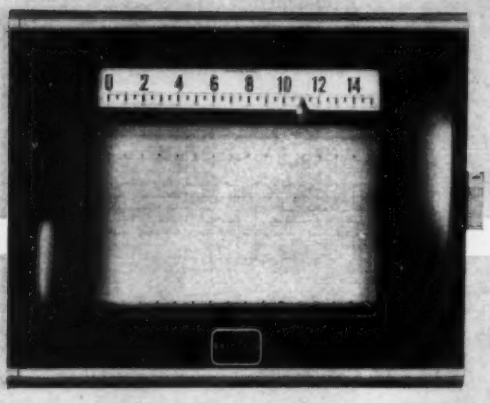
- Reamers, drills and cutters of various sizes were run together in the above vacuum unit.
- Preheat 1550° F. High Heat 2250° F.
- Surface Condition — Clean and Bright as shown in photograph taken after treatment.

See this process. Call for an Ipsen representative to give you full details.

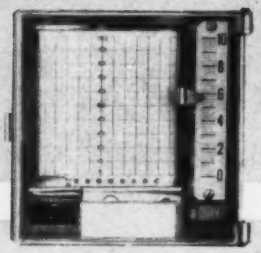
AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. DEPT. 723 P.O. BOX 500 ROCKFORD, ILLINOIS

Circle 1602 on Page 48-B

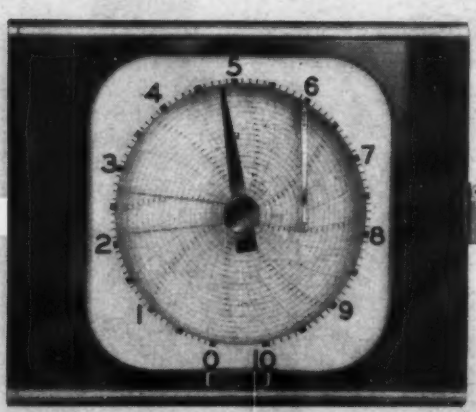


Dynamaster Electronic Potentiometer Pyrometer—Strip-chart model records on chart 11" wide, 120' long.



Miniature Electronic Dynamaster Pyrometer—Records on 3" strip-chart. Indicator model features easy-to-read 9" scale length.

Bristol Millivoltmeter Pyrometers—Free Vane* pyrometer controllers (shown) or indicating types. Many control modes available.



Dynamaster Electronic Potentiometer Pyrometer—Round-chart model records on 12" chart, indicates on extra large scale.

MODERN PYROMETERS...key to profitable use of HEAT

Bristol recording and automatic controlling pyrometers for temperatures up to 5000°F can help you increase product uniformity, cut fuel and maintenance costs

Bristol makes a wide range of pyrometers for every requirement: Electronic potentiometers, millivoltmeter and radiation types . . . for furnaces, ovens . . . every type of heating equipment, every kind of fuel. The reliability and accuracy of these precision instruments have been proved in thousands of installations.

Take just one advanced Bristol instrument, for example, the Electronic Dynamaster* Potentiometer Pyrometer:

CONTINUOUS STANDARDIZATION PLUS ACCURACY OF STANDARD CELL

Continuous standardization in Dynamaster Electronic Pyrometers requires no dry-cells, **but still retains the precision standard cell for highest stability and accuracy of voltage reference.** Results: No interruption to operation, no batteries to change. And here are just a few of the Dynamaster types available:

A model for every requirement: Dynamaster Pyrometers are available as single-pen, two-pen, and multiple-record (up to 24 points) *strip-chart* instruments and as *round-chart* instruments.

Electric and pneumatic controllers: Both strip- and round-chart instruments are made in a very wide variety of controllers that meet every furnace and oven control requirement, including the following in a great many forms:

Electric Control—on-off, proportional input, 3-position, proportioning, proportional with automatic reset, and time-program.

Pneumatic Control—on-off, proportional, and proportional with reset.

Miniature Dynamaster Pyrometer: Full plug-in flexibility . . . takes only 5" x 5⅛" of panel space, but has same basic accuracy, same time-tested operating principle as full-size Dynamaster pyrometers described above. Ideal for graphic panels and centralized recording or indicating of large numbers of variables. Either electrical or pneumatic control types available.

Write for complete data on Bristol Pyrometers—and remember Bristol offers a complete line of thermocouples and pyrometer accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. *T.M. Reg. U. S. Pat. Off.

BRISTOL... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Circle 1603 on Page 48-B

HERE'S THE MOST ADVANCED TEMPERATURE INDICATING CONTROLLER AVAILABLE!

NEW SENSITROL PYROMETER COMBINES

- **Daystrom Creative Engineering**
- **Weston Accuracy and Reliability**

The Daystrom Sensitrol Pyrometer is now available for your *most critical* temperature control applications. This new instrument has an accuracy of ±0.5%, full scale, and a sensitivity of ±0.1%, thanks to a dependable Weston galvanometer sensing element. A non-contact photocell actuates the control . . . completely eliminating drag on the galvanometer.

Here are a few of the many other features offered by Model 8800 Sensitrol Pyrometer: Solid state throughout. Plug-in modular construction for simplicity of maintenance . . . no soldering required. Only 10$\frac{3}{16}$" x 7$\frac{1}{2}$", the unit can be flush or panel mounted. It has a long 6-inch scale, range of 0-400 to 0-4,000 F, with set points adjustable over entire range. Signal lights at each end of the scale make it easy to read control position from a distance. Two modes—ON-OFF or three position.

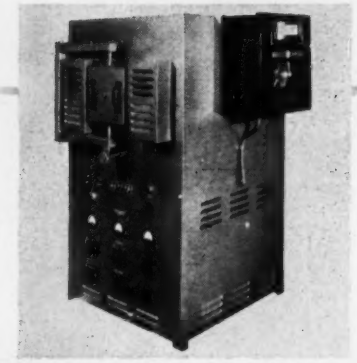
Write today for complete technical data or applications assistance on the new Sensitrol Pyrometer—a product of unexcelled Daystrom experience and traditional Weston accuracy! Daystrom, Incorporated, Weston Instruments Division, 229 Manchester Road, Poughkeepsie, N. Y.

International Sales Division, 100 Empire St., Newark 12, N. J. In Canada: Daystrom Ltd., 1480 Dundas Highway East, Cooksville, Ontario.

DAYSTROM, INCORPORATED
WESTON INSTRUMENTS DIVISION
Reliability by Design

Circle 1604 on Page 48-B

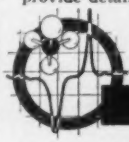
Variety of applications with pinpoint accuracy



HARROP ELECTRIC FURNACES with Non-Metallic Resistor

Versatile, rugged design gives Harrop NMR Series furnaces great latitude in the application of heat to materials ranging from ceramics and ferrites to metals and cermets. Controls heat and measures temperatures accurately under continuous operation to 2820° F., and higher for intermittent operation. Oversize components and refractory linings prevent accidental lining damage. Six standard models range in setting space from 7 x 9 x 9 inches to 36 x 45 x 41 inches. Available in four cabinet forms and furnished with instrumentation to meet any specific requirements. Two models are equipped with mechanical or hydraulic elevator.

The NMR Series is typical of all Harrop furnaces . . . designed to meet specific requirements but with scope to meet a variety of firing needs. Harrop experience is available to help find solutions to any problem involving controlled application of heat or the accurate measurement of temperature. Harrop experience cuts across the full range of engineering skills to provide detailed recommendations based on complete analysis of materials, range, control and objective. For prompt and interested evaluation of any firing problem, theoretical or practical, write Dr. Robert A. Schoenlaub, Director of Research, 3470 E. Fifth Ave., Columbus 19, Ohio.



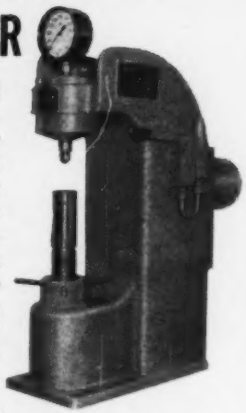
HARROP PRECISION FURNACE CO.

(A Division of Harrop Ceramic Service Co.)

Circle 1605 on Page 48-B

Simple, low-cost bench-type brinell

HARDNESS TESTER



Motorized hydraulic pump and fingertip control through time-proved relief valve prevent operator from overloading or applying load too fast. Load verified on sensitive gauge. The Riehle Bench-type Brinell Hardness Tester is so economical and simple to operate that now even the smaller shops can do accurate Brinell testing. ¾" stroke permits anvil height to remain fixed when testing a series of similar thicknesses. Accuracy unaffected by frequent changing of Brinell loads. Other Riehle Brinell hardness testers include portable and floor mounted models. Write for literature and name of nearest Riehle representative. Address Dept. MPS-1061.

OTHER MODELS AVAILABLE — Floor-mounted, bench and portable models for Vickers, Knoop, Rockwell & Superficial Hardness Scales also available with a full selection of accessories for special applications.

BOOTH 429 NATIONAL METAL EXPOSITION

Riehle®

RIEHLE TESTING MACHINES DIVISION OF
American Machine and Metals, Inc.
EAST MOLINE, ILLINOIS

Circle 1606 on Page 48-B

Conversion Services—Prompt Deliveries

Extrusion

In this illustration, the product is tubing: beryllium (left) and zirconium (right). Whether the material is common or rare, the configuration simple or complex, one of Nuclear's three extrusion presses* can handle it, and at least one of Nuclear's 275 technical people has had experience related to it.

*Our fourth is on order.

A

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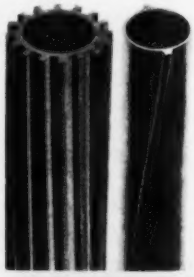

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- For evaluation or conversion services
- For technical or marketing consultation
- To supplement your product development dollar

Call Nuclear Metals now.

Circle 1607 on Page 48-B

WE MAKE SPECIAL STEELS—ESPECIALLY WELL

HIGH SPEED STEELS
TOOL STEELS
STAINLESS STEELS
ALLOY STEELS
FORGED ROLLS
EXTRUSION PRESS PARTS

MARATHON

SPECIALTY STEELS, INCORPORATED

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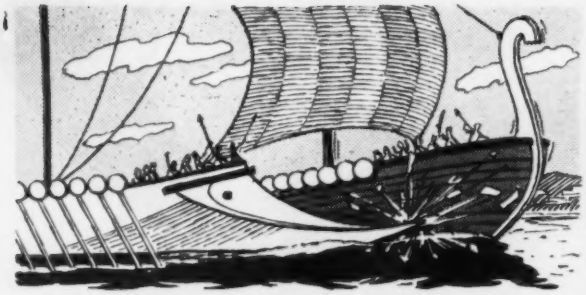
Circle 1586 on Page 48-E



"SPIKES" IN LAPPING COMPOUND CAN DO LOTS OF DAMAGE, TOO!

Long, sharp "spikes" that gouge or even just scratch, don't belong in diamond lapping compound. To keep them (and *all* unwanted matter) out of Trulap® Diamond Lapping Compound, we make Trulap in a laboratory, using blocky diamond shapes of uniform size—"spikes", "blades", "jumbos", "fines" are out. So, with Trulap, you get the greatest lapping mileage for least cost because Trulap diamond powder is the right shape, accurate size, evenly dispersed throughout the paste. For extra value, new Trulap contains Granulaide*, which keeps new Trulap working for you long after ordinary compounds would be expended. Available in America's widest selection of accurately graded particle sizes and in dispensers from 2½ gr. up. Write for bulletin.

*T.M. OF W.T.T. CO. FOR ITS SURFACTANT.

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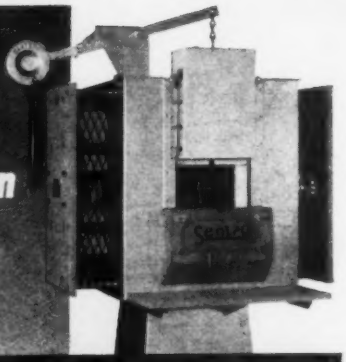
A research development of Wheel Trueing Tool Company. Over 50 years a leader in diamond products.

Circle 1609 on Page 48-B

Vital Production Tools Warrant



SENTRY HARDENING

Correctly hardened tools are essential to high production. This is where Sentry Furnaces with the neutral Diamond Block Atmosphere fulfill their greatest need, offering reliable hardening without expensive supervision, and at, low, low investment and operating cost.

Your high speed tools achieve maximum hardness without risk of scale or decarburization, maintain sharp cutting edges longer, step up production.

For free demonstration hardening bring your tools to Booth 930 at the Detroit Metal Show.

Sentry TRADEMARK **ELECTRIC FURNACES**

242-1

Request Catalog 10-P • Write **THE SENTRY CO., FOXBORO, MASS.**

Circle 1610 on Page 48-B

PLASMARC

NEW...HIGH-SPEED FUSION OF VERY-THIN DEPOSITS WITH CONTROLLED DILUTION

From LINDE, the inventor of plasma arc processes, comes PLASMARC weld surfacing—the first process for depositing very-thin fused overlays of heat-, wear- and corrosion-resistant materials, with controlled dilution, at high speeds. PLASMARC weld surfacing utilizes the intense heat (30,000° F.) of a constricted plasma arc created within its torch and transferred to the work. The metal is fed into the torch as a powder. It is carried to the work in the plasma jet formed from argon gas. *Check these features:*

- Penetration into base precisely controlled to .005-in. and up.
- Dilution with base precisely controlled to 5% up to 50%.
- Deposits as thin as .010-in., as thick as 3/16-in., in one pass.
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- Speeds over 20 ipm at 95% deposition efficiency.
- Flatter, smoother deposits than other fusion processes.
- Wide choice of metal and alloy powders for surfacing.

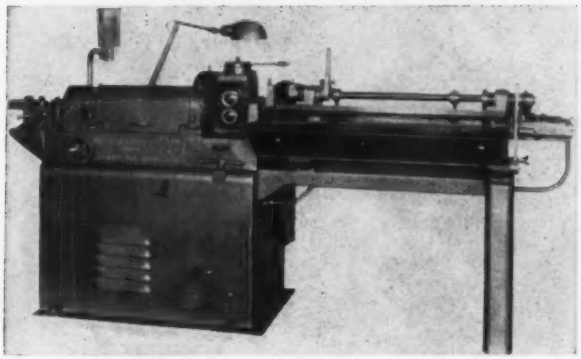
SEE IT "LIVE" AT THE METAL SHOW
Cobo Hall, Detroit, Booth 127, October 23-27

LINDE COMPANY
Division of Union Carbide Corporation
270 Park Avenue, New York 17, New York

UNION CARBIDE

Circle 1611 on Page 48-B

PATTERSON WIRE STRAIGHTENING AND CUTTING MACHINES



MODEL 2A 1/16" TO 1/4" DIA. CAPACITY

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Variable Speeds & Feeds
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Roll Type Clutch—Quick Action
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Many Other Models for Wire Up to 3/4" Dia.

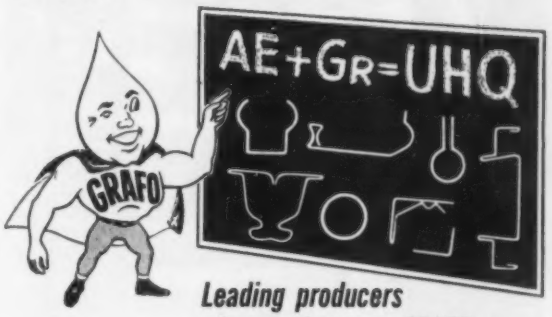
FOR THE BEST IN MODERN STRAIGHTENERS

THE GEO. C. PATTERSON MACHINE CO.

3409 Trumbull St., Cleveland 15, Ohio

Circle 1619 on Page 48-B

Happy answer to a problem!



Leading producers of extrusions use GRAFO

Many manufacturers of aluminum extrusions already know the basic answer. It's simply this: *Aluminum Extruding* plus *GRAFO* equals *Uniformly High Quality!*

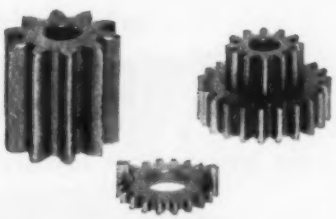
Why? Because GRAFO Colloidal Graphite dispersed in water reduces die wear, prevents sticking, gives better metal flow and improved production. *Send for booklet "The Biggest Ounce of Protection"*

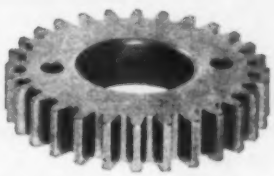
•If you have a problem of excessive temperatures, pressures or abrasion, let us help you solve it with a GRAFO Water, Oil or Alcohol Dispersion for your conditions.

GRAFO COLLOIDS *Corporation*

279 Wilkes Place, Sharon, Pa.

Circle 1620 on Page 48-B





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Take advantage of the highest quality powder metallurgy available today! If you use hobbed gears—or other structural parts—in quantity, Supermet Hi Density parts can save you big money. At a single pressing all of the gears above are produced 90% of theoretical solid, carburized conventionally, and given after-treatments such as plating (you can't do this with ordinary powder metal parts). Supermet makes gears up to 1.25 sq. in. cross-section to your specs in iron, alloy steel, carbon steel or stainless. We regularly work to ASTM B309-58T Class A and B densities. Because of our modern, fully equipped toolroom, we can readily fabricate and maintain your tooling.

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Supermet is often the "supplier of last resort"—we deliver on time those difficult powder metal parts on which others fail. Send a part print today for a prompt engineering analysis—take advantage of the strength of steel with the economy of powder metallurgy.

Circle 1621 on Page 48-B

LINDE ELECTRIC WELDING

PLASMARC

FIRST PROCESS FOR FUSED DEPOSITS (.010-IN. AND UP) WITH CONTROLLED DILUTION AT HIGH SPEEDS

SEE IT "LIVE" AT THE 43RD NATIONAL METAL SHOW COBO HALL, DETROIT OCT. 23-27, BOOTH 127

Circle 1612 on Page 48-B

ATOMIC AGE WHITESMITHS*

*Artisans in White, Rare and Precious Metals

SUPER ALLOY FORGE
INCORPORATED
JOHN E. CONNOLLY — ACADEMY 9-7860
HAMBURG, MICHIGAN
See us at the Detroit Metal Show Booth 1010

Circle 1613 on Page 48-B

COLUMBIA TOOL STEELS

Uniform High Quality — Adequate Inventory
Delivery as Promised — Product Innovation
Engineering Service

Product of Skilled American Workmen
Who Buy American

BRANCH STOCKS in Chicago, Milwaukee, Detroit, Cleveland, Cincinnati, St. Louis, and Los Angeles. REPRESENTATIVES in Cambridge, Erie, Louisville, Newark, Omaha, Portland and West Hartford.
Circle 1614 on Page 48-B

NEW NEW NEW NEW NEW NEW NEW NEW NEW

when it MELTS you know the *temperature!*

NEW *Markal* THERMOMELT TEMPERATURE INDICATORS

With Handy Adjustable Holder

The easy modern way to determine exact working temperatures!

Just mark or stroke the surface with THERMOMELT . . . when it reaches the desired temperature, the mark liquefies. There's no guesswork, no wasted time or material . . . THERMOMELT is the quick, precise way to determine heating temperatures. Accurate to within ±1%.

A Stik For Every Temperature from 113° F. to 2000° F.

SEND TODAY for free THERMOMELT literature and pellet sample (indicate temperature desired).

ALSO AVAILABLE IN LIQUIDS AND PELLETS for inaccessible or hard-to-measure applications. Wide range of temperatures.

Made by the Manufacturers of Markal Paintstik Markers and Protective Coatings.

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Circle 1615 on Page 48-B

REVCO

ULTRA-LOW TEMPERATURE CABINETS

for

- Research
- Storage
- Seasoning
- Testing

Seven Revco cabinets, both chest and upright styles, are available. Capacities range from 1.5 to 6 cu. ft. in chests and to 22 cu. ft. in uprights. Units provide temperatures to —140° F. controllable within ±1°. Optional accessories are offered. Immediate delivery on all units.

For your FREE copy of the helpful folder, "Selecting a low temperature cabinet," write Revco, Dept. MP-101.

Industrial Products Div.
REVCO INC.
Deerfield, Michigan
Setting Trends in Refrigeration Since 1938

Circle 1617 on Page 48-E

ACCURATE
DEPENDABLE
LOW COST

HEAT TREATING

with

YOUNG BROTHERS OVENS

designed and built
for individual product
and process requirements

batch and conveyor types up to 1000° F

Write for Bulletin 157

YOUNG BROTHERS CO.

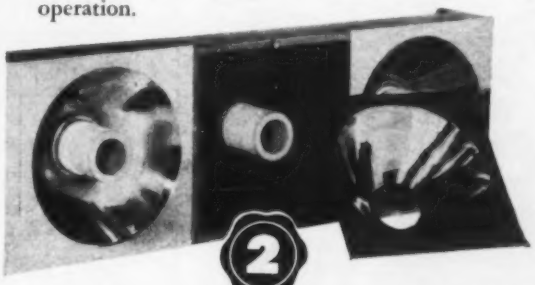
1829 Columbus Road • Cleveland 13, Ohio
Over 60 years of service

Circle 1618 on Page 48-E

3 Important FIRSTS from driQuik infra-red ovens

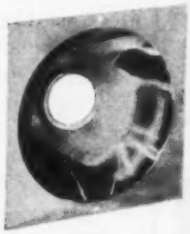
1 BACK-LOADING Infra-Red Generators

In the past, all infra-red generators have been installed or replaced from the front side of the ovens. Now with new driQuik construction, replacements are made from the back, and can be made by *one* man. Changes can be made while the oven is in operation.



2 REFLECTOR REMOVAL without Generators

Now driQuik reflector removal is simplified with new slip-on design. Only driQuik has it.



3 Stainless Steel REFLECTORS AVAILABLE NOW

Available on all models. Recommended where an unusual amount of hard-to-remove foreign matter is deposited on the reflectors and must be removed periodically. Also where highly corrosive vapors are present, or where exposed to the weather.

driQuik DIVISION — **DRY CLIME LAMP CORP.** GREENSBURG, INDIANA

Circle 1616 on Page 48-E

SEE PAGE 49

for a preview of UNITRON'S complete line of metallurgical microscopes. We invite you to bring along a sample of the type of material you use in your work for visual examination and photography with a UNITRON.
Our optical engineers will be available to discuss your individual problems and suggest suitable instruments for your purpose.

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DETROIT METALS SHOW
OCTOBER 23-27
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UNITRON
INSTRUMENT COMPANY • MICROSCOPE SALES DIV.
66 NEEDHAM ST., NEWTON HIGHLANDS 61, MASS.

Circle 1625 on Page 48-B

BEHIND THE BYLINES • BEHIND THE BYLINES • BEHIND THE BYLINES •

work; he's currently president of the local school board in Chardon, Ohio.

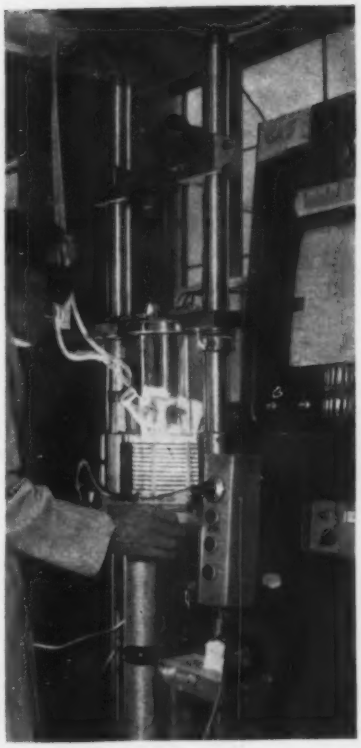
The 4000° F. creep-rupture machine shown below – that's Ward Simmons examining it – has just been added to the creep laboratory at Battelle Memorial Institute in Columbus, Ohio. Ward has been evaluating the high-temperature properties of metals since 1941 and his article on superalloys ("What Alloy Shall I Use . . . for High-Temperature Applications Above 1200° F.?, p. 84) is based on this experience. His scholastic background includes a degree in metallurgical engineering from the University of Minnesota School of Mines and Metallurgy (1939).

His workaday interests are reflected in his spare-time activities. He is on several technical committees and is chairman of Sub-

committee XII on Specifications for Super-Strength Alloys of A.S.T.M. Committee A-10 and is a member of the A.S.T.M. Administrative Committee on Papers and Publications and the Ohio Valley District Council. He is also chairman of the Special Purpose Alloys Subcommittee of the S.A.E. Nonferrous Metals Committee.

The rest of his time is spent on his hobbies – oil painting and photography – and in keeping up with his four-acre "farm" and 150-year-old home near Delaware, Ohio, where he lives with his wife Eleanor and three of his four children. (The oldest daughter is married and lives in Arizona and, in fact, Ward finished this article just before he left on a vacation trip to visit her.)

Dan Maykuth and Russ Ogden (who tell you what refractory metal to use for ultrahigh-temperature applications in their article on p. 92) have been conducting research on nonferrous metals together since Dan came to Battelle in 1947. (Russ, shown on the right, with Dan, in the photo, has two years seniority over him.) They are noted particularly for their early research on titanium alloys and of late for their work on the refractory metals – more and better refractory metal alloys will be forthcoming based on the research they are now conducting. Coincidentally, they both have the same alma mater, Michigan College of Mining and Technology – Russ graduated in 1941 and Dan in 1947 – and both went on to graduate work and master's degrees from Ohio State University. Currently, Russ is chief and Dan assistant chief of the nonferrous metallurgy division at Battelle.



Temperature Control Within ±0.3C

Using the meniscus as his guide, an operator at Shockley Semi-Conductor Laboratories pulls a silicon crystal for use in the development of a four-layer diode while L&N's Speedomax G C.A.T. control system holds temperature of the melt within ±0.3 degree!

Precise and completely dependable, this control system continuously regulates the output of an induction generator through a magnetic amplifier and saturable core reactor . . . and, if desired, can be used with an external program unit.

This system is helping not only Shockley Laboratories but also many other investigators, suppliers and producers of electronic equipment to grow crystals of consistently high quality.

Process Data Sheet 660(1) will bring you more information on L&N's temperature control for crystal growing. But no matter what your instrument needs—when quality counts, it'll pay you to see your L&N field engineer. Write your nearest L&N office or 4927 Stenton Ave., Phila. 44, Pa.

LEEDS NORTHRUP
Instruments Automatic Controls • Furnaces

Circle 1622 on Page 48-B

a vacuum pump as quiet as a . . .

Steady and silent. That's the new Stokes Series H Microvac pump. Unique dynamic balancing provides hushed operation. And the compact Stokes pump saves up to 50% in valuable floor space.

Find out all the reasons why you get *more pumping performance per dollar* with Stokes Microvac pumps. Just write: Vacuum Equipment Division, F. J. STOKES CORPORATION, 5500 TABOR RD., PHILA. 20, PA.

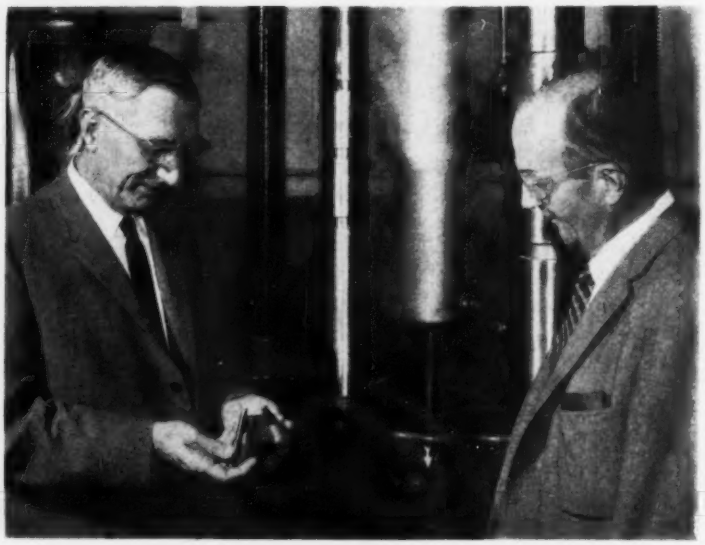
STOKES

SEND TODAY
for your free
Vacuum Slide Calculator.

Circle 1623 on Page 48-B

Russ and his wife like to travel. When at home, they garden and dream of new places to visit by way of their stamp collection. This past summer Dan had to forsake his usual hobbies – golf and hi-fi – to oversee the construction of a new home which he and his wife and four children (two girls and two boys) hope to move into this month. Again coincidentally, Russ and his wife will be moving into a new home this month, too.

The rapid growth of the cryogenic industry has focussed increased attention on metals to use in fabricating vessels and equipment for low-temperature service. Our report on this area is presented by George H. Zenner ("What Metals Shall I Use . . . for Fabrication of Cryogenic Vessels and Equipment?", p. 110), who has had many years experience in the cryogenic field. (He's shown in the photo below, left, with C. M. Heath, metallurgy consultant for Linde who provided much of the information for the article.) He entered industry early, at the age of sixteen, and spent six years at Western Electric Co.'s Hawthorne Works, graduating from the company's three-year tool design apprentice course and becoming a punch and die designer. He enrolled in the University of Illinois in 1923 and after graduation four years later (with a B.S. degree in mechanical engineering), joined Linde. His first job was in the cryogenics lab-



oratory measuring density of acetylene-acetone solutions. When Linde embarked on its own design and construction program for producing and distributing liquid oxygen (about 1930), he began working in the design and development phases. Since then he has directed various projects in this area, including the first cold converters made of Everdur, first commercial vacuum-powder insulated storage tank, first liquid oxygen tank car and first successful liquid oxygen pumps. He was named assistant manager of the engineering laboratory at Linde in Tonawanda, N.Y., in 1951.

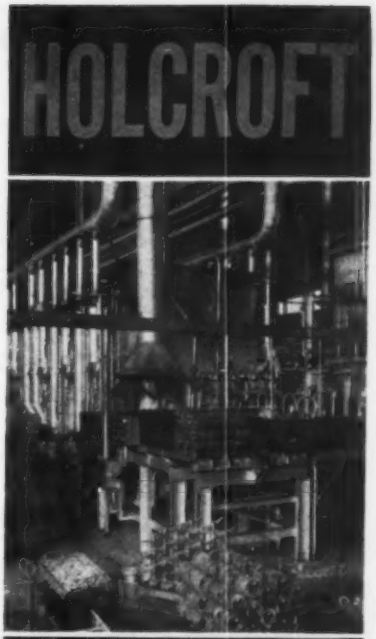
Among his recent projects was writing one of the sections in the book Progress in Cryogenics, Vol. 2, edited by K. Mendelssohn, which was published last year. Usually his spare time is devoted to golf, fishing, travel, stereo, photography, hi-fi or do-it-yourself projects.

Lloyd Lockwood (who is responsible for the section on magnesium in the article, "What Metal Shall I Use . . . for High-Strength Welded Structures?", p. 116) expected to be assigned to corrosion studies when he started to work in the metallurgical laboratory of the Dow Chemical Co. in July 1955. He was fresh from Ohio State University where his master's thesis in metallurgical engineering had been on the passiviation of Type 304 stainless steel. (He entered Ohio State after receiving his B.S. degree from Michigan College of Mining & Technology.) But instead Dow placed him in the welding development group, and he has been completely absorbed in welding ever since.

An expert on magnesium welding, he has branched into aluminum in line with the broadening interests of the Dow Metal Products Co. division. (He is now research and development engineer in the division.) Earlier this year he completed a week-long course in advanced aluminum welding principles sponsored by Aluminium Ltd., Kingston, Ont. (In the photo above, taken during the course, he is shown in the center.)

Twenty-two years in the thermostat metals department of Metals & Controls Inc. is the background for Ray Sears' article "What Metal Shall I Use . . . for Resistance-Welded Thermostats?". Formerly chief process engineer, he was named senior application engineer for the department in March. A graduate of Tufts College with a B.S. in chemical engineering, he is a member of the thermostat metal committee of A.S.T.M. and on the roster of S.A.E.

He and his wife, Ruth, celebrate their 20th wedding anniversary this month. His interests include gardening, sports, travel and reading.



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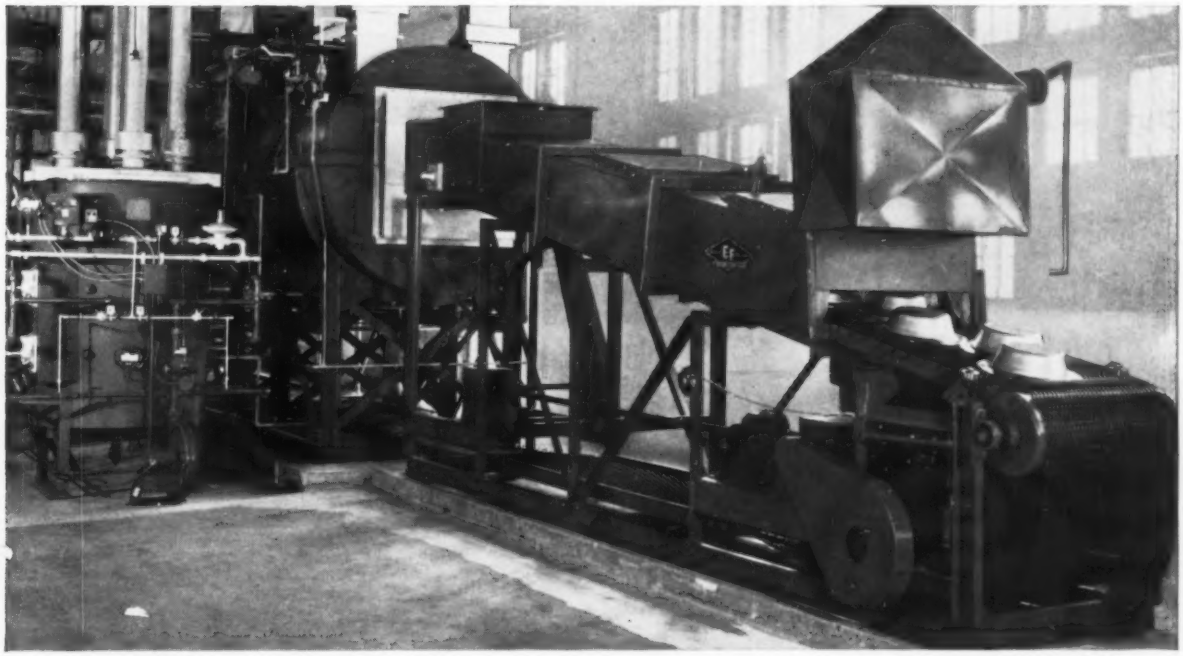

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